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UNIVERSITY OF DURHAM

Some aspects of the Medical Geography
of County Durham

by

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— (Hatfield College)—

Thesis submitted for the degree of Doctor of Philosophy

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ABSTRACT

This thesis is concerned with the investigation of disease patterns at the intermediate or regional level, in relation to the existing framework provided by a number of recent surveys of disease mortality at the national scale. The latter had drawn attention to the particularly poor disease experience of County Durham in relation to the rest of the United Kingdom. A number of previously unmapped data sources, particularly in the case of morbidity, are investigated with the aid of some original cartographic devices and data handling techniques, which are described in chapters two, three and eight.

Chapter four is concerned with a geographical analysis of three consecutive epidemic cycles of measles during the period 1961-65. The epidemiological significance of living density in the determination of diffusion patterns is demonstrated, and atmospheric pollution is invoked as a possible aetiological factor in the initiation of epidemicity. Chapter five deals with a similar detailed study of the geographical distribution of tuberculosis, and particularly the respiratory form of the disease, in County Durham as a whole. The influence of density factors (particularly overcrowding) socio-economic status and housing conditions upon the disease pattern is investigated by means of multiple regression techniques. Chapter six provides a more detailed study of the relationship between housing and respiratory tuberculosis for three selected local authorities in south-central Tyneside. Chapter seven represents a by-product from the main lines of inquiry, and is concerned with the possible involvement of iron ore dust as an aetiological factor in the causation of certain ill-defined stomach disorders at Consett during the winter of 1964-65.

Section III concludes the study with a preliminary survey of mortality patterns in County Durham, between 1963-67, for the major causes of death. A number of tentative conclusions are drawn from these distribution maps, but only where the evidence appears to be consistent with

accepted medical theory.

It should be noted that two papers embodying the partial results of this investigation, and in particular chapters two and nine, have already been published.

To

Reginald Alec Young

(1892-1963)

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Johnathan C. Young

BIBLIOGRAPHIC NOTE

Where quotations or material are drawn from recognised sources, the name of the author or source, together with the year of publication, is cited in the text - e.g. (Stamp 1964). Where appropriate, the exact pagination is also indicated in the text thus - (Stamp 1964:115). A consolidated list of references appears at the end of each chapter.

SECTION I

AIMS AND METHODS

"He who, whether by original observations, or by legitimate deduction drawn from the observations of others, shows the identity of, or points out an analogy between disorders hitherto commonly thought to be distinct and dissimilar complaints, by so far as he accomplishes this does he assist in simplifying medicine, and consequently, contributes towards its advancement, theoretically as well as practically."

George Todd (1855)
Trans. Epid. Soc. London p.82

Chapter 1.

Introduction

1.1. Introductory remarks

The mapping of disease and the subsequent analysis and interpretation of the resultant patterns is a fundamental yet surprisingly neglected application of the geographer's craft. "The whole field is wide open but the difficulty is to know where to begin." (Banks, 1959:206). The breadth and complexity of the subject matter, and the inherent difficulties of obtaining, processing and analysing the medical statistics cannot be denied. However, the geographer, by virtue of his basic training, is well equipped to tackle this type of investigation, in which "strands must be drawn from a diversity of sources to provide an overall synthesis" (Learmonth, 1961:19). Ideally, the geographer should be just one member of an interdisciplinary research team, which directs its attention towards the solution of specific medical problems. In practice this is rarely possible, and as a result the geographer has so far been forced into a position in which he is primarily concerned with the production of disease maps per se: the subsequent analysis and interpretation of the patterns being left almost exclusively to medical practitioners. As Stamp comments, "medical men with the requisite training and skill are rare. On the other hand, geographers with cartographic training and skill have rarely the medical knowledge to handle the data available" (Stamp 1964:14). However, with the increasing application of new and more sophisticated geographical techniques, it is proving possible, indeed almost obligatory, for the geographer to penetrate more deeply into the disease patterns he has derived; to compare these with the distribution of other known variables, and then to suggest what appear to be reasonable hypotheses on the basis



of the evidence before him. In this way, more conventional and sophisticated medical enquiry is able to utilise available resources more efficiently, by focussing its attention on the more striking anomalies suggested by the disease maps. It is also possible for the medical research worker to compare his own findings with the results obtained by a completely different and independent line of enquiry.

Although a number of historical references are introduced in sections dealing with specific disease categories, it is not the purpose of the study to present a comprehensive review of major studies in medical geography. Nevertheless, it is perhaps worth noting here a limited selection of sources which proved to be particularly valuable during the initial stages of the research programme.

A most useful summary of the historical evolution of medical geography is contained in Howe's "National atlas of disease mortality in the United Kingdom" (Howe, 1963 & 1970). A similar bibliographical review of statistical aspects of the subject was undertaken by Serfling (1952) in his "Historical review of epidemic theory". In addition, the B.Litt. thesis by Paula Cook (1963) entitled "The geography of human disease" provides not only a glossary of major terms, but also an outline of the more important statistical techniques which are available to the geographer. Of a more general nature, Gale's (1959) "Epidemic diseases", and Clark-Kennedy's (1957) "Human disease" were found to be extremely useful as introductory texts to a totally unfamiliar field.

At first sight the study of medical geography might be regarded as a peripheral and rather specialised area of geographical activity and concern, dealing as it does with an immense diversity of knowledge. Indeed, "no class of geographical factors has been shown to be without influence on the disease pattern." (Banks 1959:215) However, if one regards the study of geography as being concerned with 'human ecology'

in its broadest sense, then the study of the spatial distribution of disease emerges as an important core element in the overall discipline, since it constitutes an extremely significant contact zone between man and environment. Viewed in this way, health may be regarded as an approach to a state of total adjustment of man to environment, while ill-health or disease springs from a maladjustment or imbalance in this relationship. Unfortunately, the definition of good health (or 'well-being', the term used by W.H.O.) proves extremely difficult to define in concrete terms, since such a state is not automatically achieved as a result of an apparent absence of clinical manifestations of disease. As a result it is usually necessary to adopt a rather indirect approach - viz. the investigation of disease, or the deviations from good health - in order to assess the relative health of the population under consideration.

It is perhaps misleading to refer to disease in general, since the term embraces a multitude of types and conditions, ranging in severity from the trivial to the ultimate of death. "Diseases manifest multiple personalities just as do living creatures and social institutions. The various moods which they display in different circumstances and at any given time reflect the dominant aspect of the relationship between the disease process and the life of man in society" (Dubos and Dubos, 1953). Consequently, each category of disease should be regarded as presenting an entirely different problem, often demanding a completely new approach and the application of a totally different set of techniques. In each case, the geographer must be ready for the unexpected, and must be prepared to adapt his line of approach accordingly. Preconception should not be allowed to preclude the improbable.

1.2. Mortality

Thus far studies in medical geography have tended to concentrate

upon the mapping of mortality statistics. Death is a finite event which can be established both in time and space, and as such it is only very rarely likely to go unnoticed or unrecorded. In England & Wales, death registration has been legally required since 1875, although in practice mortality records are available for most areas of the country long before that date. Despite the universality of death registration, there are a number of important limitations which must be borne in mind during subsequent analysis. The most significant of these are briefly discussed below.

Firstly, death rarely results from a single cause, although for the purposes of registration only one cause of death may be recorded. In a study in the United States of America, Krueger (1966) found that in 58% of all mortality records two or more causes of death were mentioned on the death certificate. For individuals aged 85 or over the figure rose to 72%. In many cases it is extremely difficult to distinguish between the primary cause of death (which will be used in the compilation of mortality statistics) and the secondary cause(s). "Death due to pneumonia, for example, may be the coup de grace that occurs at the terminal end of the biological gradient but may mask the basic cause of mortality" (Banta and Fonaroff 1969:89).

Secondly, a severe source of error can be introduced as a result of incorrect diagnosis of the cause of death. Quite obviously this will inevitably depend to a large extent on the diagnostic expertise of the medical practitioners involved. A recent study by Heasman and Lipworth (1966) demonstrated the disparity between initial clinical diagnosis of cause of death, and that subsequently established by detailed pathological examination. In only 45.3% of cases (out of a total sample of 10,000 deaths) was agreement found between the initial and subsequent diagnoses. It was discovered that tuberculosis, lung cancer, bronchitis and cancer

of the liver were under-diagnosed for this reason, while cancer of the stomach, diabetes and cerebral haemorrhage were over-represented.

A third, although less significant, source of error is introduced into the data through deliberate misregistration of the true cause of death by general practitioners. This may occur as a result of pressure from the family of the deceased wishing to suppress or conceal the fact that death resulted from a disease which is disapproved of by society at large - e.g. syphilis or alcoholism. Alternatively, the doctor may record a 'convenient' cause of death, such as cancer of the stomach, instead of the 'true' or suspected cause which may prove considerably more difficult to diagnose - for example cancer of the spine. The latter diagnosis might well involve the doctor in the added complication and trouble of arranging an official autopsy.

Fourthly, the place of death may not necessarily correspond with the normal place of residence. Indeed, in a world of increasing mobility it is becoming progressively more difficult to relate the death location to the area in which the individual lived for the greater part of his life. For example, a Sheffield steelworker moving to the south coast of England upon retirement, and dying a short while later of bronchitis, is thereby creating an anomaly in the overall pattern of disease, since his death must inevitably be regarded as a manifestation of particular aetiological factors which are not represented in the place of death. In the same way, the increasing diurnal migration of population, generated as a result of journey to work, makes it even more difficult to investigate precise relationships between disease and environment in terms of mortality experience. Furthermore, in the case of some chronic and degenerative diseases, death may occur perhaps twenty or thirty years after the initial onset of the disease. During that time, the particular environmental circumstances responsible for eliciting

the initial symptoms of disease - e.g. bad housing conditions, poor nutritional standards or air pollution levels - may have been entirely erased from the landscape or society. For this reason it is important to keep in mind certain historical perspectives when attempting to analyse more recent mortality patterns.

Since 1952 deaths occurring in hospitals have been re-assigned to the place of normal residence of the patient. Since 1957 deaths occurring in other institutions such as old people's homes have been similarly re-assigned, provided that the deceased has not been continuously resident in the institution for more than six months prior to death (Hewitt 1956). This has had the effect of reducing the substantial over-registration of mortality in the urban areas, where most hospitals are located.

The present manual of causes of death, prepared by the World Health Organisation (seventh revision, 1958) recognises 1,000 categories of mortality, each of which is assigned a unique reference code. For general purposes, this list is normally abbreviated to 50 major group headings, although in England & Wales the Ministry of Health and the Registrar General employ a classification of only 36 major causes of death. Unfortunately, the rapid advance in medical knowledge and the corresponding refinement of diagnostic procedure has meant that the system of classification itself has had to undergo a significant evolution. Accordingly, extreme caution must be exercised when attempting comparisons of mortality experience over protracted time periods. In most cases it is necessary to make quite extensive adjustments to the mortality data to make allowance for classificatory changes - see for example the study prepared by the U.S. Department of Health, Education and Welfare (Campbell 1965) concerned with mortality trends in England & Wales.

1.3. Morbidity

Since a particular individual experiences a considerable number of distinct episodes of illness during his lifetime, the analysis of mortality patterns alone provides an inadequate picture of the health status of a population. Unfortunately, ill-health or 'morbidity' is an extremely difficult phenomenon to measure, or even to define. Logan and Brooke (1957:16), recognising the subjective nature of morbidity, state simply that "a person is ill if he feels ill". However, if this latter definition is adopted, the more significant elements of the morbidity pattern tend to become obscured by the mass of trivial complaints and symptoms. In this context Logan and Brooke (1957) report that during the first quarter of 1951, which was dominated by a severe epidemic of influenza, a morbidity rate of 75% was reported for England and Wales. The figure for the corresponding quarter of the preceding year was 71%: or only 4% lower!

Whereas mortality can usually be precisely recorded in both time and space, there are a considerable number of difficulties in making similar measurements in the case of morbidity (Sanders 1964). In the first place, a single episode of illness may extend over a protracted time period, particularly in the case of an insidious disease such as tuberculosis. As a result it may prove extremely difficult to ascertain with any degree of certainty the actual date of onset for the disease. Secondly, an individual may experience a number of separate bouts of the same disease, thereby further complicating the recording process. Thirdly, it should be recognised that a single disease type may elicit totally different responses among its victims. Thus, whereas one person may eventually die from an attack of influenza, another may experience only a sub-clinical attack, and be completely unaware that he has in fact contracted the disease (Bailey 1955:51). Moreover, evidence seems to

suggest that the nature of specific diseases is capable of substantial mutation through time. This applies particularly to the virulence of the more common infectious diseases such as measles and scarlet fever, both of which were regarded as very serious afflictions at the turn of the century (Anderson 1957:192).

1.4. Data sources

Even today, medical statistics for most countries in the world are incomplete, if not totally unavailable. As a result, variations in disease incidence between countries may often prove to be more apparent than real, in so far as they may reflect basic differences in the completeness and accuracy of data collection. As Banks (1959:214) comments in connection with the valiant work of Jacques May (1950a) in mapping disease at the world scale, "the maps form at one and the same time an atlas of disease and an atlas of ignorance..... Alas! We still lack the facts only too often."

Nevertheless, the situation in much of the developed world is far more encouraging. In the case of the United Kingdom, a comprehensive system of disease registration has existed since the end of the nineteenth century. Registration of births and deaths, together with a selected number of notifiable diseases, is required by law, and this has yielded a considerable wealth of published statistical material for a substantial time period. In addition, a far greater store of material remains unpublished and virtually untouched from a research point of view. This material is held both in the local authority health offices and in the files of individual general practitioners. These latter sources provide the medical geographer with the opportunity of delving into more local patterns of disease.

1.4.1. Published sources

The Registrar General's Statistical Review which is published

annually, devotes part I entirely to medical statistics. Mortality is tabulated by cause for the administrative counties of England and Wales and the county boroughs. The annual totals of notifications for a number of infectious diseases are also given for individual county boroughs, together with the urban and rural totals for each of the administrative counties.

The Registrar General also publishes a decennial supplement to the census returns entitled "area mortality", which, although not yielding a greater spatial division, does at least provide a comprehensive age breakdown for the major causes of death. The major disadvantage of the supplement is that, although the data refer to a census year (e.g. 1951), they are not usually available until seven years later (i.e. 1958).

Of a more general statistical nature are a series of papers produced by the General Register Office and entitled "Studies on medical and population subjects". The topics vary widely, and include "Cancer statistics for England and Wales", "General practitioners' statistics", and "Hospital morbidity statistics: a preliminary study of inpatient discharges". In the main they are non-geographical in approach, and consequently rarely attempt to investigate the distributional patterns of the medical data presented for units less than the standard region. As such they can only provide a useful summary, and a wider frame of reference for more detailed study.

In addition, the General Register Office produces a weekly return of statistics for England and Wales, entitled "Births and deaths, infectious diseases, weather". In particular table II tabulates the number of births and deaths - distinguishing deaths of infants under 1 year of age - during the period of one week, for individual counties of England and Wales, and by cause. Table IV records the "Notifications

of Infectious Diseases in the week ended (e.g.) 3rd April 1970". The data for the latter table are given by local authority for the following 25 selected categories of infectious disease:-

Scarlet fever, whooping cough, measles, acute poliomyelitis (paralytic and non-paralytic forms), tuberculosis (respiratory form), tuberculosis of the meninges and C.N.S., diphtheria, smallpox, cholera, plague, tuberculosis (other forms), meningococcal infection, anthrax, infective acute encephalitis, post-infective acute encephalitis, typhus fever, relapsing fever, dysentery, ophthalmia neonatorum, puerperal pyrexia, acute pneumonia, paratyphoid fever, typhoid fever, food poisoning.(1)

1.4.2. Unpublished sources

Data for the official returns noted above are supplied by individual local authorities, who maintain two separate running registers. One records mortality and the other morbidity. These registers are themselves compiled from the records of the local registers of births and deaths, and from reports submitted by medical practitioners.

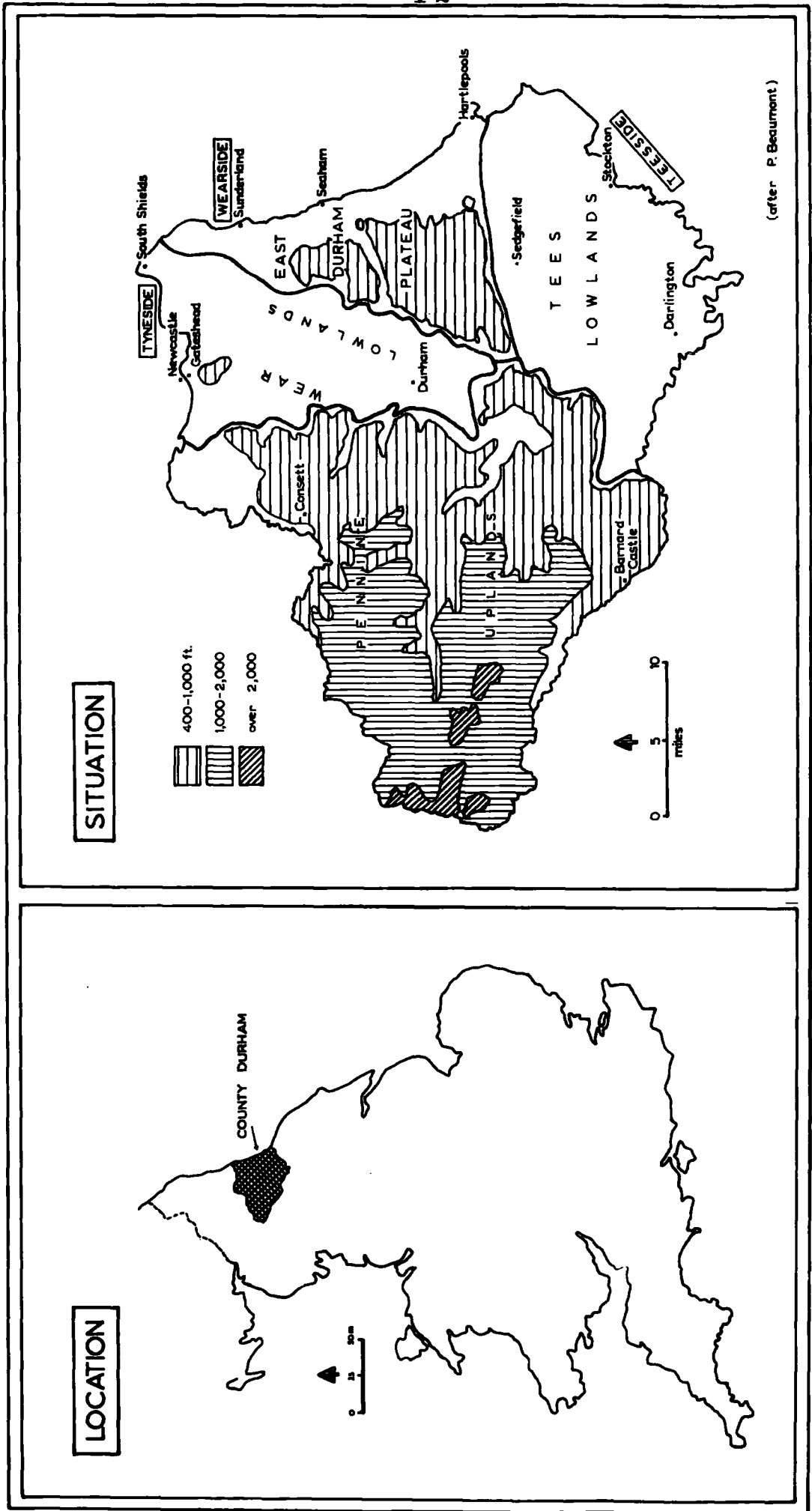
The mortality register, which in some cases is only retained for a period of twelve months, records details of the date of death; name, sex, age, occupation and place of usual residence of the deceased; together with a statement of the major cause(s) of death.

The notifiable disease register, available in most cases for a much longer time sequence, records the name, sex, age and address of the patient; the name of the recording doctor; the date of hospitalisation (if any); and the nature of the disease. In a limited number of cases a separate register is kept of tuberculosis notifications in an effort to preserve a measure of confidentiality.

1.4.3 Statistical limitations and considerations

Some of the more important limitations and disadvantages of mortality and morbidity statistics have already been alluded to in sections 1.2. and 1.3. above. However, more detailed discussion of

(1) This represents the situation as at 1st January 1967. Since then the list of diseases has been increased to 28. Disease categories such as yellow fever and infective jaundice have been added, while others such as acute pneumonia have been deleted.



(after P. Beaumont)

FIGURE 1.1.

these and other statistical considerations is reserved until the introduction of specific chapters, since the problems inherent in dealing with particular data sets vary quite substantially from one disease category to another.

1.5. The study area

It had originally been proposed to study some aspects of the medical geography of North-east England, thereby selecting a geographical region with particularly well-defined natural, as well as administrative boundaries. However, it soon became apparent from the wealth of statistical material available that such a large study would be impracticable unless it was to attempt no more than a generalised survey of the medical geography of the area. Under the circumstances, there appeared to be two alternatives: either the survey area would have to be severely reduced in size, or a more detailed investigation would have to be carried out, involving perhaps only a single disease category, for the whole of North-east England. It was decided that the former alternative was the more acceptable, and as a result the survey area was limited to County Durham, together with its five associated county boroughs. Despite this considerable reduction in the study area, it could well be argued that by considering only County Durham one was in fact achieving a relatively representative transect through the different environmental facets of the North-east as a whole. The County exhibits a wide range of different physical and cultural environments (figure 1.1.). Sparsely populated upland areas of dispersed settlement in the west contrast sharply with the urban complexes in south Tyneside, Wearside and north Teesside to the east. The intervening zone of the county is characterised by a close network of nucleated towns and villages (the majority associated with mining activity) superimposed upon an existing pattern of agricultural settlements. This area Hedden (1969:6) has described as a "single urbanised region rather than an

interconnected system of separate towns". The availability of such a diversity of environmental types enables the geographer to determine whether or not this is reflected in a similar variety of response in terms of disease experience. It also provides an opportunity to investigate through disease certain functional relationships which inevitably exist between these different types of environment.

It is of course true that by adopting purely administrative boundaries as the framework for the study area, contiguous areas, displaying a considerable degree of homogeneity in respect of their disease experience, were inevitably and artificially separated from each other. This was particularly true of Tyneside and Teesside where two large urban complexes were dissected by the county boundary. Indeed, experience would suggest that disease regions are rarely co-extensive with administrative units (Howe, 1959:205), although for most purposes the latter may be regarded as suitable sample points for investigating patterns of disease. Providing reasonable care was taken not to disregard the importance and significance of such spatial linkages in the disease pattern during subsequent analysis, it was thought unlikely that this factor would detract substantially from the overall validity of the study.

On the other hand, the adoption of a purely administrative unit as the spatial framework of the study may be deemed to offer a number of distinct advantages, not least of which is concerned with the availability of comparable statistical information for a wide range of social and economic parameters collated on the same basis. Moreover, in many ways the existing hierarchy of administrative units, ranging from the county borough to the urban and rural district, may be deemed to have evolved, at least in part, in response to a large number of historical and environmental factors. Thus the resultant network of administrative divisions may not in reality be quite as artificially

contrived as they might at first appear.

At the time of the 1961 Census, County Durham had a resident population slightly in excess of $1\frac{1}{2}$ millions.⁽¹⁾ This provided a sufficiently large 'population at risk' to yield meaningful disease patterns without the constant fear of statistical insignificance. At the same time, the volume of data collection and processing demanded by a total of forty local authority areas can be kept within manageable proportions, thereby permitting the investigation of a number of different categories of morbidity and mortality. Nevertheless, as McDonald and Clemence (1965) state, "No community is ideal in every respect for a community health study; each investigator seeks the best possible compromise between purposes and resources." (p. 9)

1.6. Spatial and time considerations

1.6.1. Scale

Stamp (1964:21) has recognised four levels of study for the medical geographer, namely, the world, the continental, the national and the local scales. Each level provides the researcher with a completely different view or perspective of the disease situation, whilst at the same time presenting its own peculiar difficulties and drawbacks. In connection with the study of disease at the local level, Stamp believes "it to be a very neglected line of research, and one which is crying out for investigators."

However, it should perhaps be stressed that although such local studies have an intrinsic relevance and value in themselves, they are substantially enhanced by constant reference to a wider frame of reference. It is for this reason that the local situation should wherever possible be viewed in relation to the national or even the world situation.

(1) Regrettably, comparable figures for the 1971 Census are not yet available, since during the intervening period the Urban District of Billingham and the municipal borough of Stockton-on-Tees were amalgamated with adjacent authorities from the North Riding of Yorkshire to form the new County Borough of Teesside.

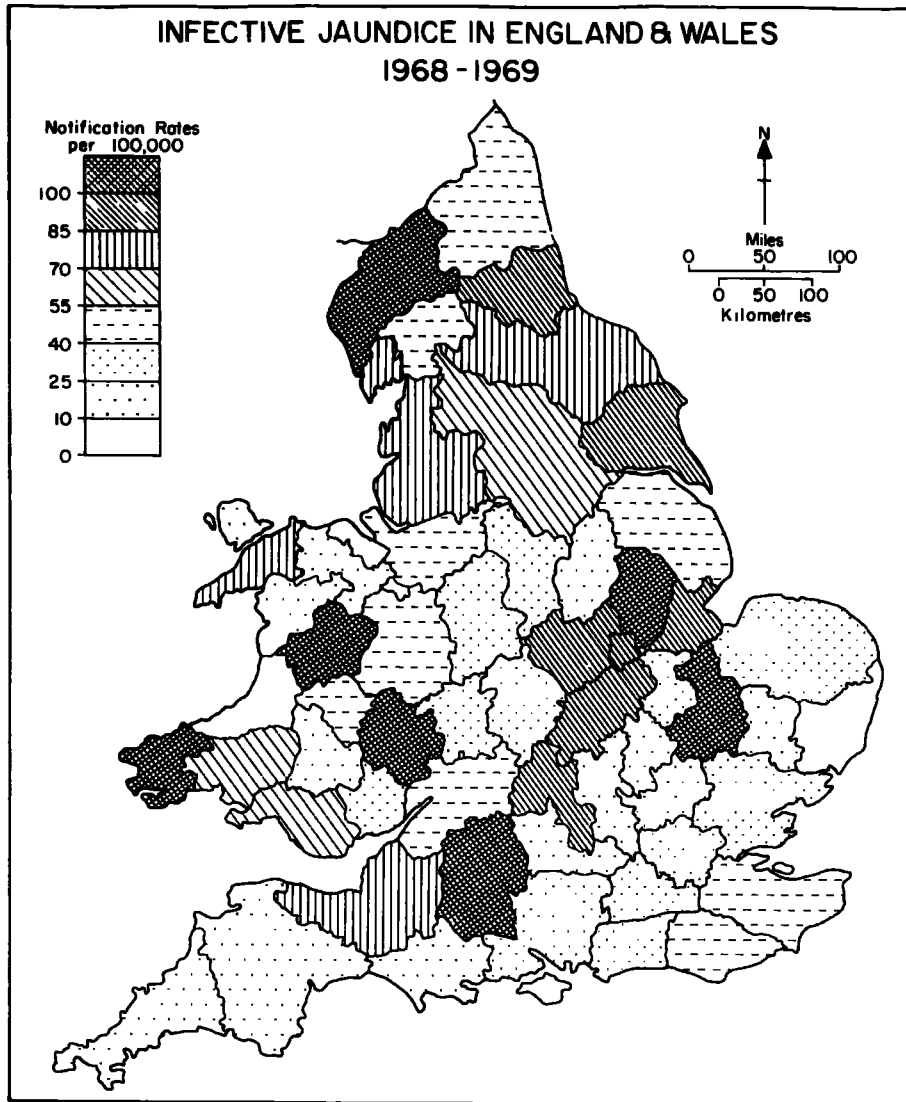


Figure 1.2.

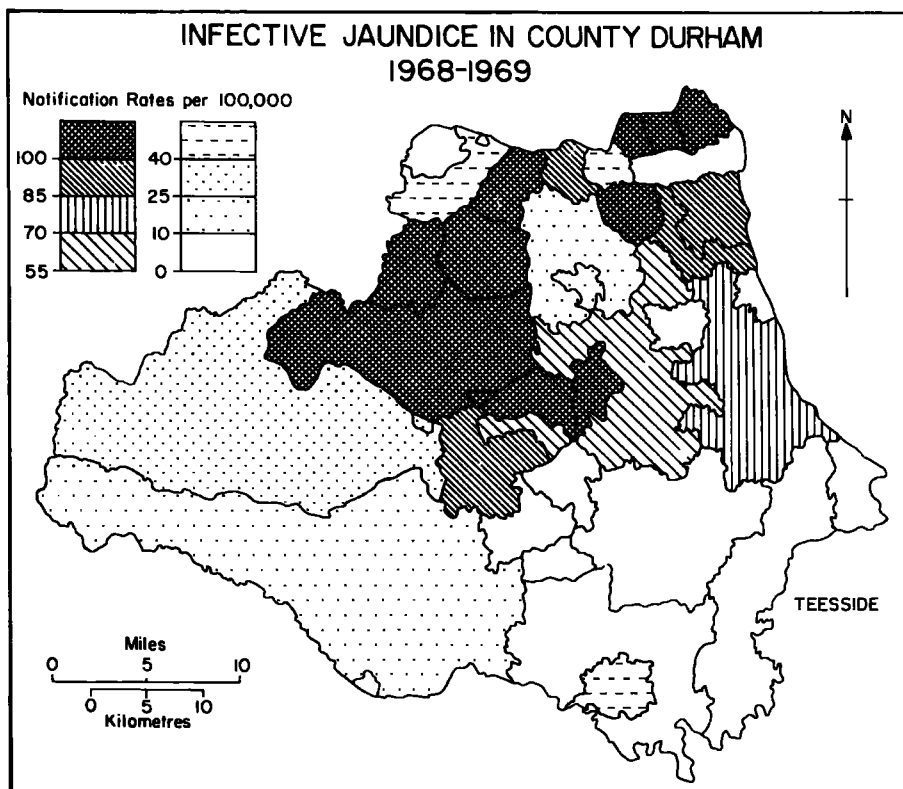


Figure 1.3.

Mapping at substantially different scales can often produce contrasting impressions of the disease situation for a particular area. Consequently, the choice of an appropriate scale for mapping must be regarded as a matter of fundamental importance. The choice of too small a scale may often mean that many of the meaningful variations in the disease pattern at the local level may become obscured. On the other hand, mapping at too large a scale may tend to detract from the overall significance of the resultant maps, by virtue of the small number of cases included in individual local areas. Taken to an extreme, the local mapping of disease can degenerate into no more than a visual representation of random fluctuations.

Figure 1.2. shows the distribution of infective jaundice in England and Wales for the first complete year for which the disease was officially designated a notifiable disease (viz. July 1968 - June 1969). Durham emerges as an area with a 'high' notification rate (85-99 cases per 100,000 persons) and the impression gained is that County Durham as a whole has a bad experience in respect to this particular disease. However, when the situation is viewed at the local level (figure 1.3.) it is discovered that there is in fact as much, if not more, variation in notification rates within the county than at the national level between individual counties. In particular, the south-east of Durham, with an almost total absence of the disease, contrasts sharply with notification rates in excess of 200 per 100,000 for particular local authorities in the north-west of the county and in south Tyneside. In this case, the local view is in many ways more meaningful, although both maps have their own particular merits, as well as their disadvantages. (1)

1.6.2. Time perspective

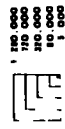
The choice of an appropriate time scale for study is dependent to

(1) Figures 1.2. and 1.3. were constructed during an investigation of infective jaundice in England and Wales (Young, 1971).

EPIDEMIC CYCLE

indicated by incidence of acute pneumonia : primary and influenzal, in England & Wales 1957

DEMOGRAPHIC BASE MAPS
Population of Counties, 1961



Acute Pneumonia Weekly Case Rates per 100,000

Suggested Possible Incidence of Asiatic Influenza : Per 100,000

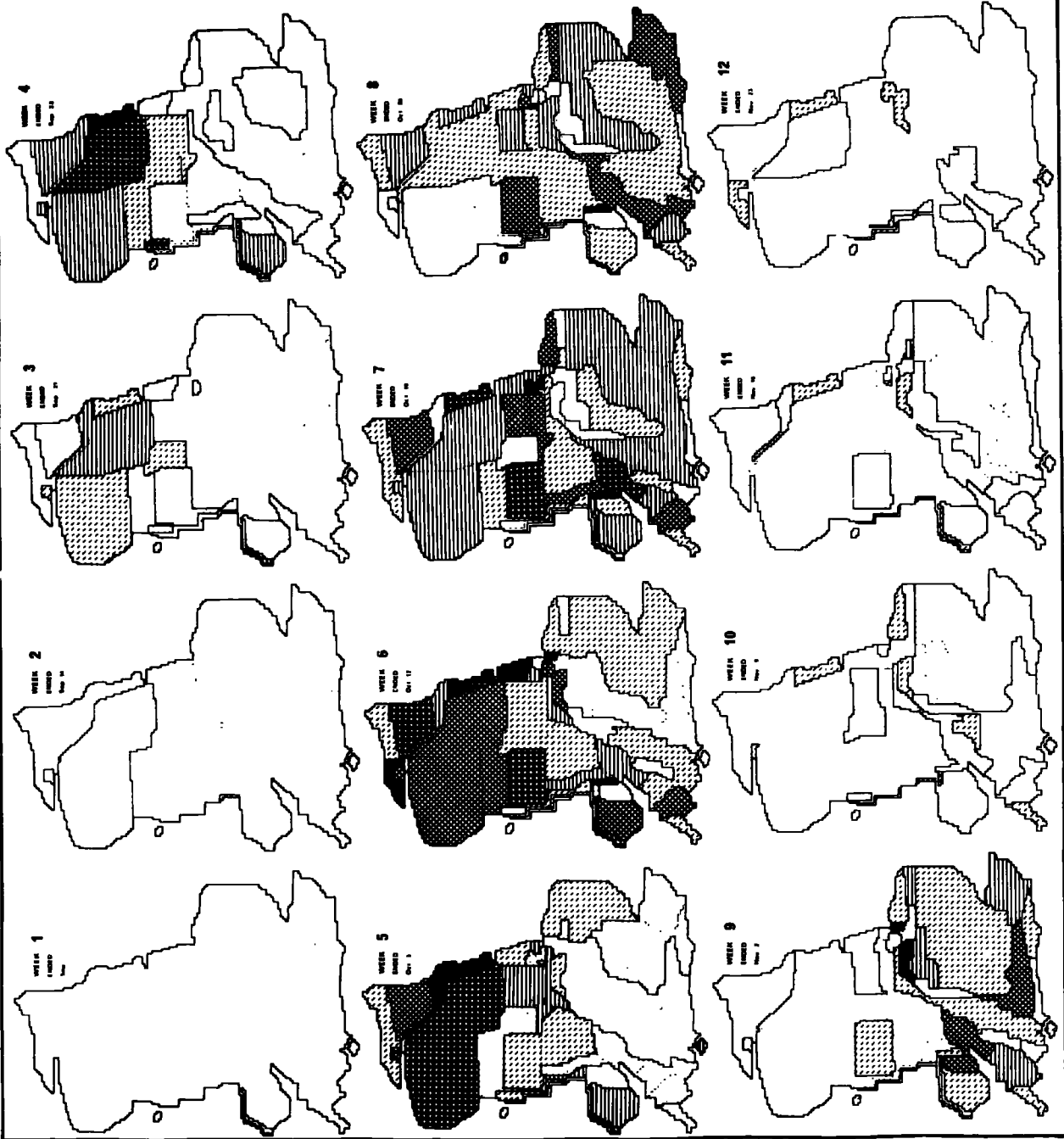
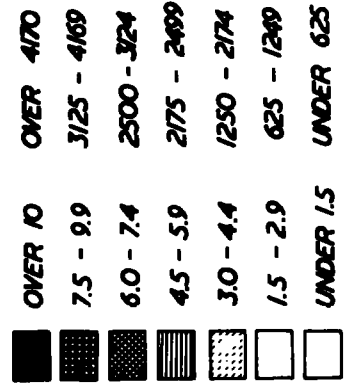


Figure 1.4.

a greater or lesser extent upon the type of disease under investigation. In the case of a highly infectious disease, the situation may change so rapidly that mapping may be possible at weekly intervals. Figure 1.4. for example shows the passage of the major wave of the 1957 asiatic influenza epidemic through England and Wales, as inferred from the notifications of acute pneumonia (Young and Hunter, 1971). On the other hand, an insidious and endemic disease such as tuberculosis may exhibit only a rather slow evolution in its spatial distribution through time, and as a result mapping may be more appropriately carried out on the basis of a year's statistics, or an even longer time period. Similarly, in the case of mortality mapping, especially at the local level, death statistics for a period of perhaps five years may be required to ensure that (a) the effects of exceptional and unrepresentative circumstances, such as a very severe winter, are not given undue emphasis, and (b) a sufficient number of deaths occur to permit the construction of maps which are statistically significant. This latter point is particularly relevant in the case of the less common causes of death, where the vagaries of chance might otherwise run riot amid small mortality scores.

1.7. Methods of approach

The basic framework for the present study was provided by statistical material obtained from official records. The general reliability of the records themselves; the completeness of cover, and the convenience of dealing with data collated for well-defined local administrative units were deemed to be extremely satisfactory bases for the proposed study. As Stamp (1964:15) comments, "My medical knowledge and training are nil. I have had to accept the medical data as published, paying due attention to the doctors' warnings as to their reliability and relevance."

At the start of the research programme, a working paper was prepared on the scope and historical development of medical geography,

in order to become acquainted with the nature of work already carried out in this field, as well as with the statistical and cartographic techniques employed. This was followed by a second working paper concerned with the evolution and development of epidemiological theory, with special reference to its application to studies of disease in a spatial context. From this latter study, the concept of 'population at risk' emerged as an important and recurring theme. It was this consideration which subsequently led to the development of the demographic cartogram and model discussed in Chapter 2. Only then was attention turned to the investigation and mapping of specific disease patterns.

1.7.1. Morbidity

The study of morbidity may be approached in one of six ways:-

- (a) Official registration of specific notifiable diseases.
- (b) General health surveys.
- (c) General practitioners' records.
- (d) Hospital records.
- (e) Claims for sickness benefit.
- (f) Miscellaneous group including school records and industrial accident records, etc.

The possibility of conducting an actual health survey in the field was rejected as impracticable on the following grounds. Firstly, the author lacked any formal training in clinical matters. Secondly, such a survey would only be feasible for a rather restricted area, given the limited resources available, and thirdly it was thought unlikely that the results from such a survey would justify the expenditure of both time and effort, bearing in mind the past experience of similar types of health surveys at the national level (Logan and Brooke 1957, Stocks 1949) and at the local level, for example in Tyneside (Spence, et al. 1954).

Similarly, the detailed investigation of hospital records; the personal records of individual general practitioners and sickness benefit records presents considerable difficulties from a geographical point of view. In most cases, the data are fragmentary and unrepresentative, and it is generally impossible to determine the size or distribution of the exact 'population at risk', because individual areal units often overlap by a considerable amount. Thus, although the value of such statistical sources has been duly demonstrated in the national context (Kay 1951, General Register Office 1953) their applicability to the geographical study of disease at the local and intermediate scale was deemed to be considerably more limited.

Having eliminated other possible lines of approach as being impracticable or unsuitable, attention was focussed on the investigation of official notification records, mostly relating to infectious diseases. Initially the statistics for a wide range of disease types were abstracted from the Registrar General's weekly returns of infectious diseases, and these were then plotted and mapped. Among the categories of disease chosen for preliminary investigation were measles, scarlet fever, whooping cough, tuberculosis, typhoid, paratyphoid, dysentery, food poisoning, infective encephalitis and pneumonia. From this extended list, only three disease types were subsequently selected for more intensive study. These were measles, tuberculosis and suspected food poisoning.

Measles was selected for study as an example of a highly infectious disease, exhibiting periods of extensive epidemic activity. It is also the commonest of the notifiable diseases, thereby yielding a sufficient number of cases to facilitate mapping at the local level for relatively short time periods. Tuberculosis, and in particular the respiratory form of the disease, was chosen as a complete contrast to measles.

Endemic in distribution, tuberculosis is an insidious disease, usually requiring prolonged periods of sustained contact between individuals for effective transmission to take place. As such it is a disease which over time appears to adjust to prevailing environmental factors perhaps more closely than most. The more localised study of suspected food poisoning at Consett was in fact a by-product of the major lines of inquiry. This apparent anomaly in the overall statistics for the county as a whole was thrown up during preliminary scanning of the weekly returns. Further investigation revealed some surprising and interesting results, thereby demonstrating the value of more detailed mapping of data within a much wider framework.

1.7.2. Mortality

In the case of mortality the geographer is compelled to rely upon statistics derived from official sources, and must therefore assume the data to be both complete and tolerably accurate for the purpose of subsequent analysis. Initially it was proposed to attempt a comprehensive investigation of the mortality patterns for County Durham for all the major disease categories; along the same lines as the study by Howe (1963) for the United Kingdom. Deaths for all causes of death were abstracted for each local authority in County Durham from the statistical records of appropriate medical officers of health for the five year period 1963-67 (inclusive). The raw data were then subjected to a process of standardisation to compensate for the effects of spatial variations in age and sex structure for the 'population at risk'. At the same time an attempt was made to enhance the statistical significance of the resultant mortality patterns by employing a framework of 'consolidated areas' for mapping all but the most common causes of death (Chapter 8). The resultant maps of mortality, for a selected number of causes of death, are presented in Chapter 9, together with a preliminary

discussion of the spatial patterns in each case. For reasons which will be discussed later, it was only found possible to consider a limited range of mortality categories. Moreover, subsequent attempts at more detailed and sophisticated analysis of the derived mortality patterns did not prove to be as rewarding as originally hoped.

1.8. Aims of the study

In undertaking the present research programme, a number of separate aims and objectives were formulated. The most important of these are summarised below. In the conclusion, they will be reassessed with a view to discovering to what extent these aims and objectives have been achieved, or to what extent they have had to be modified in the light of subsequent research experience.

1.8.1. The application of disease mapping

Perhaps the most fundamental aim of the present study was concerned with the further demonstration of the relevance and value of the map in the investigation of disease. As Stamp (1964:14) comments, "If we accept the view that the modern discipline of geography is the study of the relationships between man and his environment we are still left with the assertion that geography is the science of distributions, that its basic tool is the map and its prime function is to express facts on maps - and in other words the cartographic interpretation of data."

In particular, it was desired to demonstrate the feasibility of mapping morbidity as well as mortality at the local level. For this purpose, a number of cartographic techniques were developed or adapted.

1.8.2. Disease mapping at the intermediate scale

The majority of medico-geographical studies so far attempted have been concerned with the international (May, 1950a) and the national scales (Howe 1963 and 1970, Learmonth 1961, Learmonth and Nichols 1965)

or else the purely local scale (see for example Brownlea, 1967; Dawson, 1970). Little has been done, at least in Britain, to demonstrate the feasibility and indeed the value of the investigation and mapping of disease at the regional scale. It was hoped that this present study by concentrating upon this intermediate level^{of} investigation would be able to reduce the degree of generalisation which is inherent in the majority of national surveys. At the same time, by embracing a suitable range of contrasting environments within the framework of the study, it was hoped that it might be possible to view more clearly the influence of particular aetiological factors on the patterns of disease. In particular, it was thought likely that considerable contrasts would emerge between the urban and rural communities in respect of their disease experience.

1.8.3. The investigation of disease patterns in County Durham, per se

Previous studies at the national scale have consistently drawn attention to the fact that Northern England has displayed a particularly poor experience in respect of a wide range of morbidity and mortality categories (Ashley, 1967; Howe 1963 and 1970; Murray 1962). In a considerable number of cases, County Durham, and particularly its associated county boroughs, emerged as an extremely unfavourable area. It was resolved to investigate this situation more fully in an effort to isolate particular aetiological factors which could be invoked to explain this poor experience.

At the same time it was hoped that by undertaking a reasonably detailed investigation of the County for a sufficiently wide range of disease categories, it might be possible to build up a substantial, if not comprehensive, picture of the medical geography for a representative sample area within North-east England.

1.8.4. The development and application of particular cartographic techniques and models

Early in the investigation it became apparent that a number of cartographic techniques or aids would have to be developed or adapted to assist in the visual representation of the data. The demographic map for the County was developed using a technique described by Hunter and Young (1968). The 'epidemograph' and the computer mapping techniques were developed in response to the need for a more rapid display of disease patterns, many of which might not otherwise have warranted the considerable expenditure of both time and effort on hand mapping.

1.8.5. Data handling by computer

The sheer bulk of data involved, particularly in the case of the mortality statistics considered in Section III, made the development of a number of data handling techniques a high priority. Techniques were devised for (a) the initial storage and checking of the base data sets, (b) the compounding of the statistics into consolidated areas and (c) the calculation of age-specific and standardised mortality ratios.

In addition, less sophisticated computer programmes were developed to undertake such tasks as calculating notification rates, performing linear and multiple regressions, and working out a considerable number of correlations.

1.8.6. A contribution towards medical knowledge

Although it was never presumed that the present study would yield any major or startling medical discoveries such as those made by Dr. John Snow in 1855, it was nevertheless hoped that at least some contribution could be made to the epidemiology and ecology of specific diseases. In particular it was thought likely that the detailed investigation of epidemic spread, and the correlation of disease patterns

with a number of environmental parameters could provide extremely promising avenues for research. At the same time, it was hoped that the research programme itself would bring to light a considerable number of problems and anomalies in the disease pattern which would demand more detailed analysis and investigation by members of the medical profession at a later stage.

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Chapter 2

Demographic Base Map of County Durham

2.1. Introduction

It has long been realised by the medical geographer that many of the more conventional cartographic techniques may not necessarily provide the most appropriate visual presentation of their data. For example, the application of the dot map by Petermann to demonstrate the distribution of cholera in the British Isles during the middle of the last century was in many ways no more than a 'pale reflection of the distribution of population' at that time (Gilbert, 1958). Similarly, the plotting of standardised mortality ratios for Australia (Learmonth and Nichols, 1965; and Learmonth and Grau, 1969) by means of isopleths, tends to give undue emphasis to the virtually uninhabited core of the continent, whilst detracting from the true significance of the littoral areas, where the bulk of the population is to be found. Under such circumstances, 'population at risk' is a far more important consideration than precise spatial relationships.

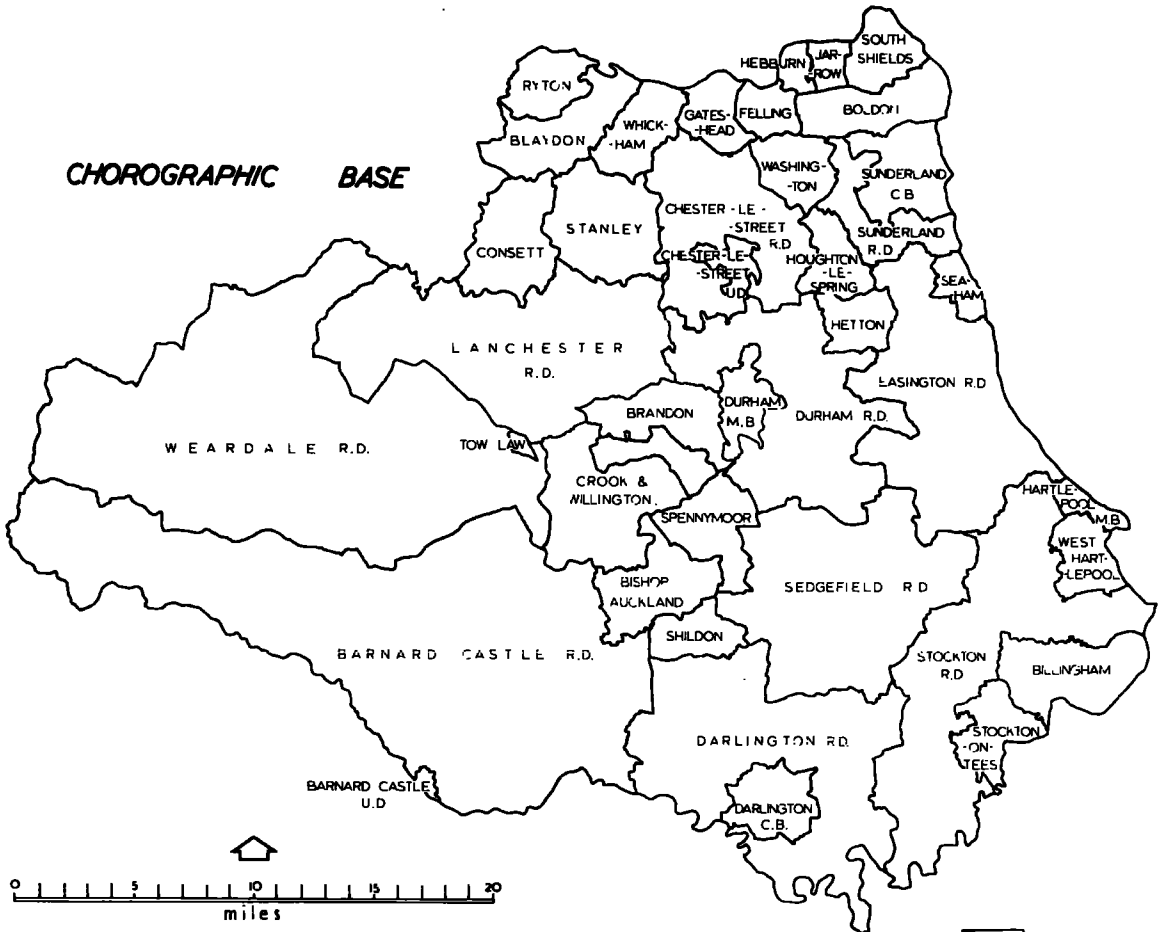
The concept of the demographic map has evolved from a number of different types of cartogram designed by workers in a variety of fields. Notable amongst these have been Raisz (1934 and 1936) with his 'value-area' cartograms, and the Woytinskis (1953 and 1955) who frequently employed 'distorted maps' in their work. More recently the idea has been adopted for use in electoral studies by Hollingsworth in the United Kingdom (1964 and 1966) and by Hughes and Savage for Australia (1967).

The adoption of the demographic map for the purposes of medical

investigation appears to have been initiated by the 'isoarchic' and 'isodemic' cartograms designed by Sutherland (1962) for Scotland. In this case, a system of sectored, concentric circles was devised for each of the main regional centres for the country, and these were then arranged in their approximate geographical location. More recently, the maps constructed by Levison and Haddon (1965) of Wilm's tumor for New York State, and the mortality cartograms of Scotland prepared by Forster (1966) have tended to place more emphasis on the use of contiguous polygons in their construction. It is perhaps interesting, and indeed surprising, to note that up to this point the application of this particular cartographic technique to disease mapping had been pioneered almost exclusively by non-geographers. It was only as a result of the valiant efforts of Howe (1968, 1969 and 1970) that the demographic cartogram became established as a useful if not an indispensable tool for the medical geographer. In this case a range of proportional symbols were located within an outline map of Great Britain in order to differentiate between rural and urban areas, and these were then choroplethed in the normal way. An additional facility was provided on the same map whereby it was possible to differentiate between statistically significant and insignificant values by means of solid or dashed outlines for each symbol.

Meanwhile Hunter and Young (1968) had been working independently on the construction of various quantitative cartograms by physical accretion methods, and the present chapter is based to a large extent on this research. More recently the cartograms which were derived by this method have been duly employed in the investigation of the diffusion of influenza (Hunter and Young 1971) and also in a study of the distribution of infective jaundice in England and Wales (Young 1971).

LOCAL AUTHORITIES OF COUNTY DURHAM



DEMOGRAPHIC BASE

Population
of Local Authorities
in 1961

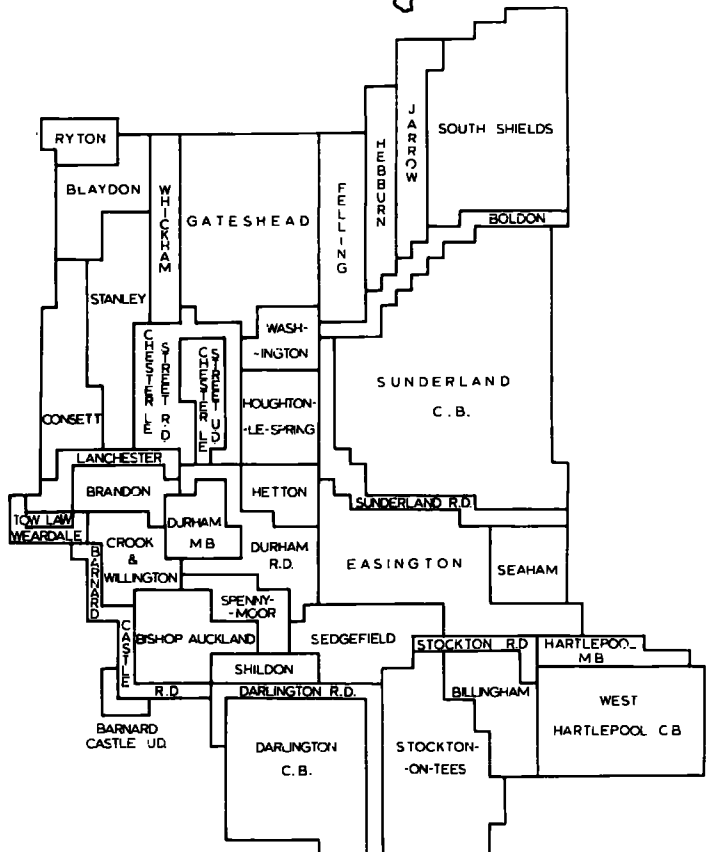
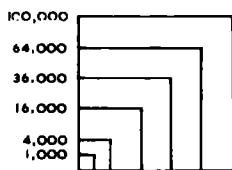


Figure 2.1.

2.2. The Demographic Map

2.2.1. Construction

The demographic map shown in figure 2.1. and employed throughout this present study relates to the census population of County Durham for 1961. Basically speaking, the cartogram is constructed by building up areas - in this case the 40 constituent local authorities of the County - from a number of small square blocks of wood each representing a single unit of population. The blocks were $\frac{1}{4}$ inch thick, sawn from $\frac{1}{2}$ inch square hardwood strip, and subsequently dyed in a number of primary colours, so that adjacent areas could be clearly differentiated in the finished cartogram.

Each block was accorded a population value of 1,000 persons, which meant that for the completed cartogram of County Durham (with a resident population in 1961 of 1,517,314) a total of approximately 1,517 blocks were required.⁽¹⁾ The population of each local authority was then expressed in terms of population units, by dividing by 1,000, and the nearest whole-number of blocks was duly assigned in each case. Polygonal shapes representing the local authority areas were then assembled in the most favourable spatial configuration possible, in an effort to retain at least the more fundamental characteristics of the chorographic base. Inevitably, however, bearing in mind the uneven distribution of population, the demographic cartogram can never hope to be more than a very restricted imitation of the chorographic base it purports to represent. Indeed, it might be argued that the more distorted the former appears in relation to the latter, the greater is the likelihood that the demographic viewpoint will be able to add a completely new dimension to the realistic evaluation of the particular geographic phenomena under investigation.

(1) The actual total was slightly in excess of this figure, due to the effects of 'rounding off' the population totals for each local authority.

In constructing this type of cartogram, the conflicting demands of three criteria must necessarily be resolved. In the first place relative population size must be retained absolutely, since the method demands the use of a fixed number of blocks in the construction of the map. Secondly, within the limits of this first constraint, a semblance of the original shape of the chorographic base must be retained. And thirdly, contiguity between local authority areas must be maintained wherever possible. Quite obviously, the situation means that there is no 'one' correct solution to the construction of such a demographic model for a particular area, although a number of workers, including Tobler (1967) have attempted to achieve such optimum configurations with the aid of quite sophisticated computer programmes. During the construction of the present demographic cartogram for County Durham (figure 2.1.) the more populous centres bordering the North Sea coast, the Tees and the Tyne were assembled first, in order to preserve the essential outline of the County. The intervening areas were then inserted, working broadly speaking from East to West. In only one case, Stockton R.D., was it found impossible to retain the desired spatial contiguity between local authority areas.

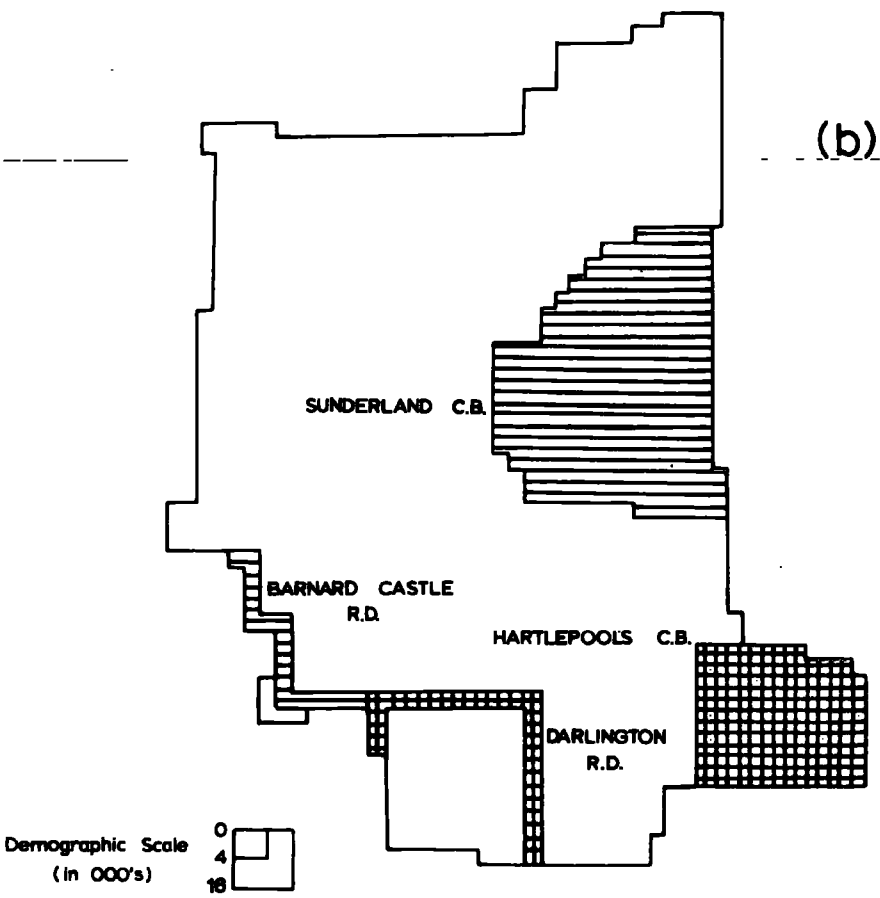
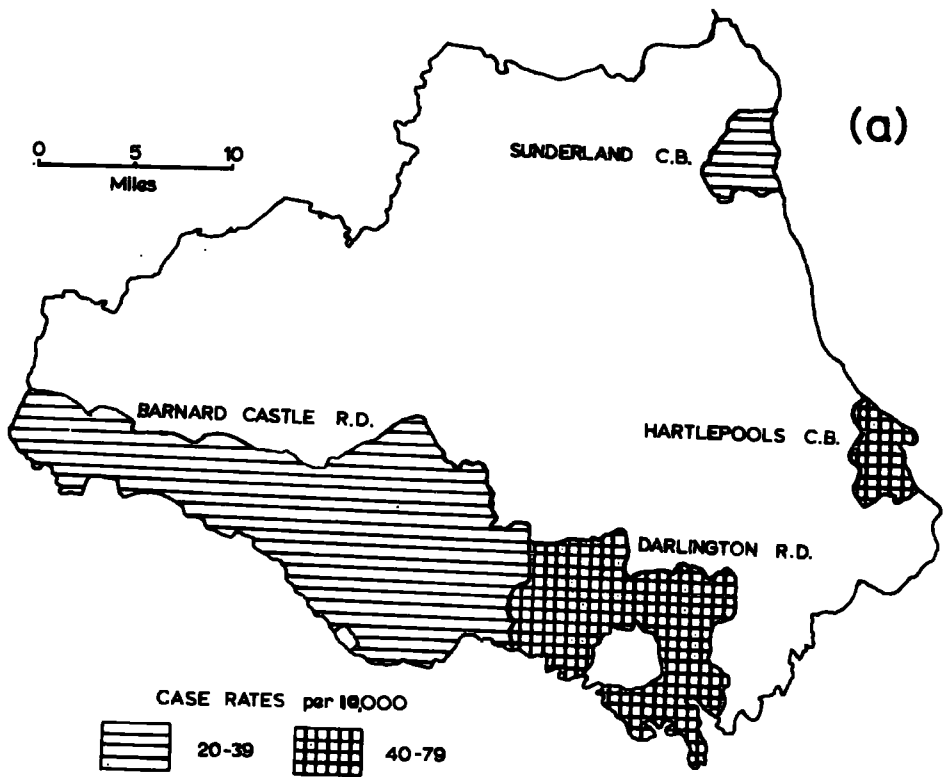
When the cartogram had been suitably assembled in block form, the resultant configuration of the model was transferred to squared paper, thereby conveniently removing any slight irregularities introduced by the individual blocks. The cartogram was then ready for choroplething in the normal way.

2.2.2. Application

It was never envisaged that the demographic map should be used in isolation, but rather as an adjunct to the more familiar and conventional chorographic representations. "It should be emphasised that

Incidence of Measles, April 1963

For Selected Local Authorities in Co. Durham



the quantitative cartogram is not a substitute for conventional mapping. It is an additional cartographic tool which can be put to a variety of useful purposes once its conventions are recognised and accepted." (Hunter and Young, 1968). This technique is particularly effective in combatting the visual supremacy of sparsely populated rural areas over the urban areas which although territorially more compact are nevertheless demographically speaking more significant. A case in point is shown in figure 2.2. which shows the notification rates for measles in County Durham during April 1963 for specific local authorities. In the chorographic map (figure 2.2.(a)) Barnard Castle R.D. appears visually dominant over Sunderland C.B., although both areas experienced approximately the same notification rate - i.e. between 20-39 notifications per 10,000 persons. However, whereas the former area with a population of approximately 17,000 recorded a mere 41 cases of measles for April 1963, no less than 684 cases were notified for Sunderland C.B.⁽¹⁾ during the same period. In this case, quite obviously the demographic map provides a far better guide as to the relative 'volume' of infection involved (figure 2.2.(b)). A similar situation is seen to exist between Darlington R.D. on the one hand and Hartlepool C.B. on the other.

In certain circumstances it may be more appropriate to construct age- or sex-specific demographic cartograms for use in the case of particular diseases or socio-economic parameters. For the purposes of this present research programme separate cartograms were constructed for the male and female populations of County Durham. However, since these were found to differ only very slightly in configuration from that constructed for the distribution of total population, only the latter cartogram was adopted for subsequent plotting.

(1) Population approximately 190,000 in 1961.

2.3. The Epidemograph

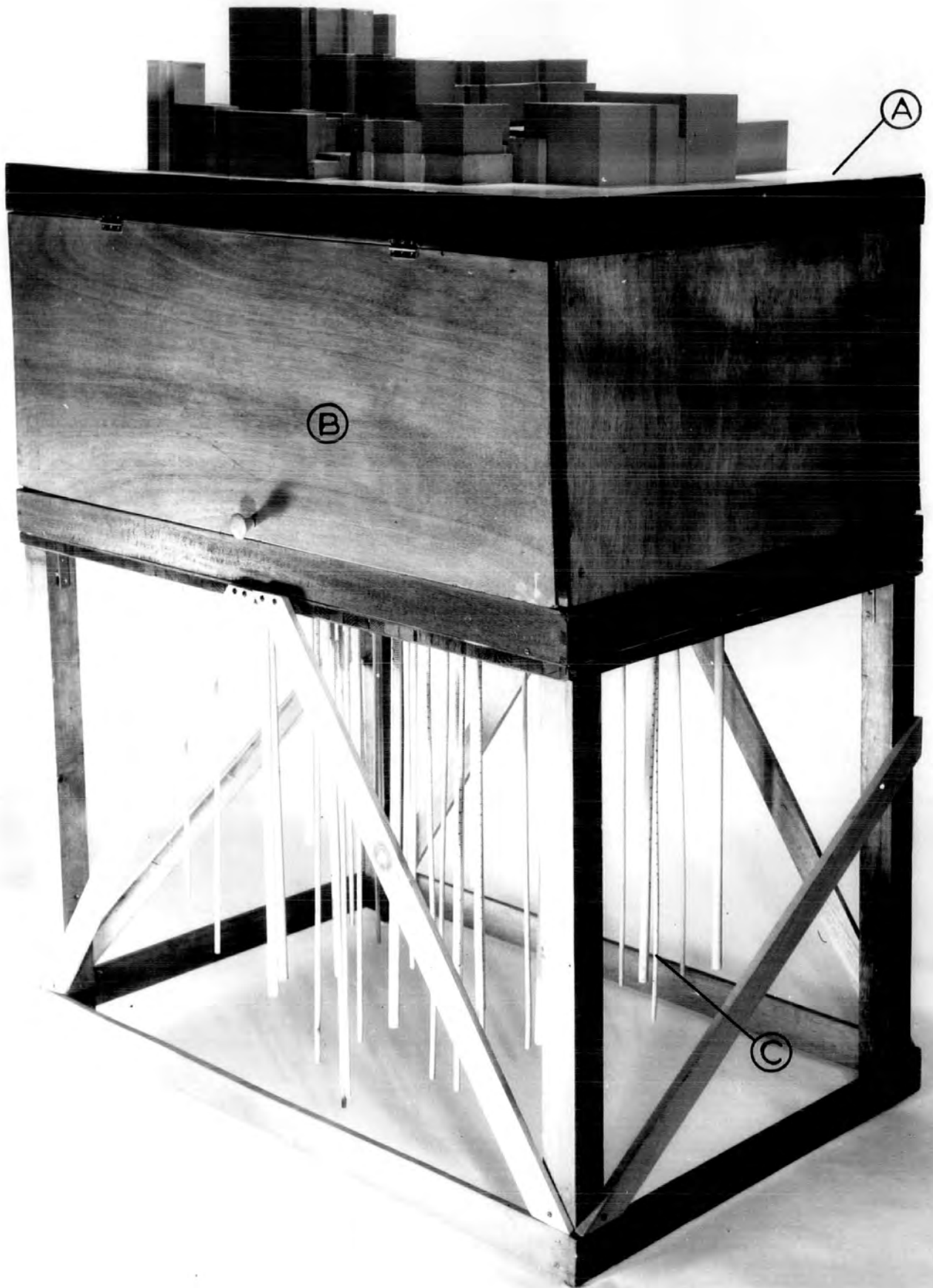
Brief mention should also be made of an additional model that evolved out of the original concept of the demographic cartogram described above.

It was discovered that hand-shading of chorographic and demographic maps was consuming a disproportionately large fraction of time. This was particularly so in the case of many of the epidemic diseases, such as measles and influenza, where a large number of choroplethed maps might be required, before more detailed analysis could begin.

In an effort to reduce the time spent in manual plotting a three dimensional version of the demographic cartogram of County Durham was constructed (see Appendix A and plate 1). By employing a system of adjustable rods the individual elements - representing the 40 local authority areas - could be conveniently raised to appropriate heights above the base level (A in Plate 1); the height of each element being directly proportional to its value for the particular parameter being mapped. In this way a cartographic representation of the distribution of a particular disease in County Durham could be produced in under five minutes by means of 40 simple adjustments of the constituent elements. This compares with a figure of approximately 20 to 30 minutes which could well be consumed in the production of even a rough choroplethic map of the same distribution. The resultant configuration of the epidemograph is then analysed, if only superficially, to see whether or not the distribution is worthy of retention for further study. If a permanent record is required then the model may be either photographed (figure 5.7.) or subsequently drawn up in finalised choroplethic form.

In the present study, the epidemograph was employed in the preliminary investigation of measles and tuberculosis (Chapters 4 and 5 respectively). However, in illustrating the final text it was deemed

EPIDEMIOGRAPH



more expedient to employ more conventional mapping techniques in most cases. Nevertheless, this method is still being utilised in more recent research projects, and it is hoped that in future it may be possible to develop this concept more fully.

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Chapter 3Choroplethic Mapping by Computer3.1. Introduction

It has already been pointed out (section 2.3.) that a considerable amount of time may be consumed in the relatively unsophisticated process of choroplethic mapping. Moreover, in many cases the configuration of the resultant map may not be visually significant, and as a result it may be discarded without further consideration. This is particularly true of disease mapping, where it is very often the unusual distribution which yields the most significant results. Quite obviously a short cut is most desirable, and particularly one which obviates the need for protracted hand-shading. It was therefore decided to write a relatively uncomplicated computer programme, which would map data by lineprinter for a particular base map - in this case County Durham.

At the outset, it must be stated that a considerable number of workers have already expended a great deal of time and effort in the development of very sophisticated programmes that are capable of generating extremely elaborate computer maps (see for example Drosness, et al., 1965; Fisher, 1969; Hopps, 1969; Rosing and Wood, 1971). In the present situation, however, it was decided to write a short programme which would be capable of producing rough working maps which would not necessarily possess many of the refinements of the more elaborate programmes such as SYMAP and LINMAP.⁽¹⁾ At the same time, it was deemed desirable to adopt a simple input procedure which could be employed by geographers with only a minimum of statistical and computing knowledge.

(1) SYMAP is a computer mapping programme developed by the Laboratory for Computer Graphics and Spatial Analysis at Harvard University. LINMAP is a similar type of programme developed by the Ministry of Housing and Local Government.

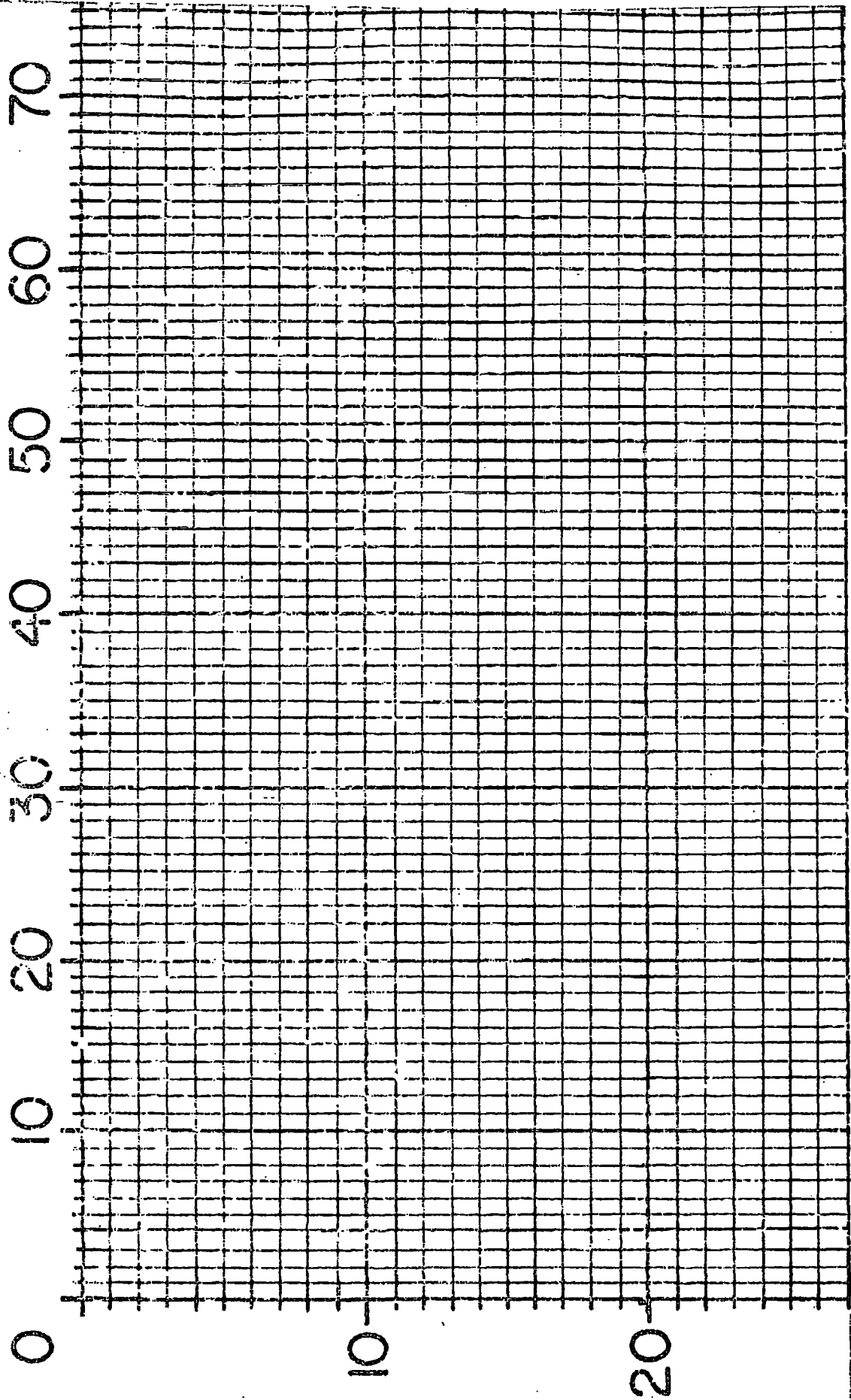


Figure 3.1. A section of the transparent grid overlay for use in computer mapping.

3.2. The preparation and running of the MAP programme

Choroplethic mapping by computer consists essentially of building up blocks or zones of shading by means of individual or superimposed strings of printed characters. Each zone of the resultant computer map corresponds to a particular sub-area of the original chorographic map upon which it is based. In the case of County Durham, the forty local authorities were adopted as the sub-areas of the base map, for which the choroplethic computer map was to be drawn.

Basically speaking, the process of computer mapping described herein consists of the following six discrete steps:-

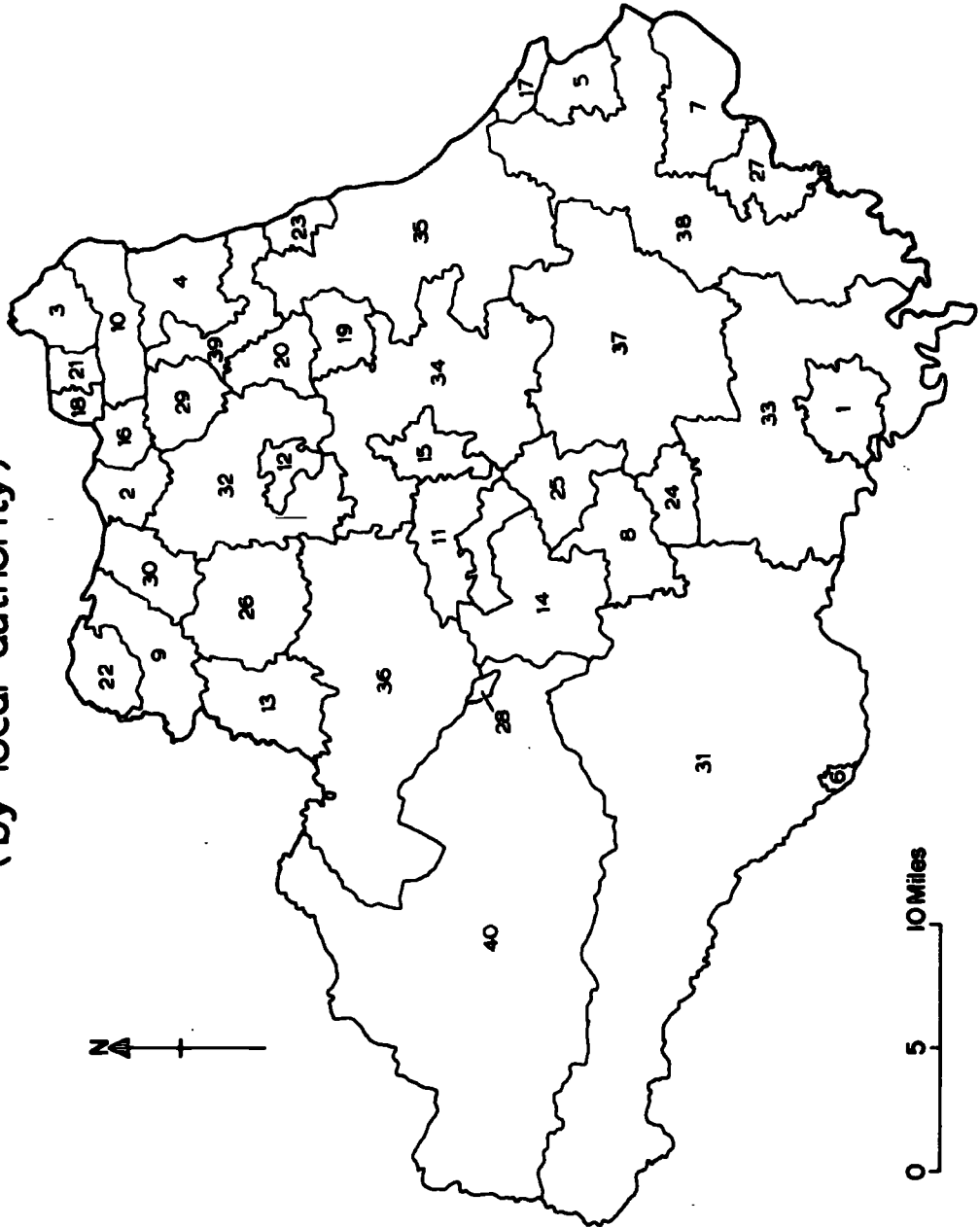
- i) the construction of a transparent grid overlay.
- ii) the production of a suitable outline base map of the area to be mapped.
- iii) the composition of a basic grid matrix from the base map and the grid overlay.
- iv) the selection of a suitable variable for mapping, and the preparation of the required data for each sub-area.
- v) the determination of appropriate class intervals.
- vi) the execution of the programme and data.

3.2.1. The transparent grid overlay

The basic grid overlay was prepared on a translucent material - in this case 'Ethulon'. Each tenth grid line was drawn in a thicker ink, and suitably numbered around the borders of the overlay (figure 3.1.). Each individual cell of the grid overlay was to represent a single symbol or character in the finished map.

In order to relate the computer print out to the original chorographic base, it was found necessary to construct the grid from rectangles rather than squares, with sides in the proportion of 5:3. This ratio represents the actual dimensions of the individual lineprinter characters, when due allowance has been made for the space between the

CHOROGRAPHIC BASE-MAP FOR CO. DURHAM (by local authority)



Local Authority Sub-area Index Number

1	Parlington C.B.
2	Gateshead C.B.
3	South Shields C.B.
4	Sunderland C.B.
5	West Hartlepool C.B.
6	Barnard Castle U.D.
7	Billingham U.D.
8	Bishop Auckland U.D.
9	Blaydon U.D.
10	Holdon U.D.
11	Brandon & Byshottles U.D.
12	Chester-le-Street U.D.
13	Consett U.D.
14	Crook & Willington U.D.
15	Durham M.B.
16	Felling U.D.
17	Hartlepool M.B.
18	Hebburn U.D.
19	Hetton-Le-Hole U.D.
20	Houghton-le-Spring U.D.
21	Jarrow M.B.
22	Ryton U.D.
23	Seaham U.D.
24	Shildon U.D.
25	Spennymoor U.D.
26	Stanley U.D.
27	Stockton-on-Tees M.B.
28	Tow Law U.D.
29	Washington U.D.
30	Whickham U.D.
31	Barnard Castle R.D.
32	Chester-le-Street R.D.
33	Darlington R.D.
34	Durham R.D.
35	Easington R.D.
36	Lanchester R.D.
37	Sedgefield R.D.
38	Stockton R.D.
39	Sunderland R.D.
40	Weardale R.D.

Figure 3.2.

characters, and the gap between individual lines of print out. (For most purposes, an overlay with grid cells of dimensions 5mm x 3mm will prove quite satisfactory; although due consideration must be given to (a) the size of the chorographic base map, and (b) the desired dimension of the completed computer map. (1)

3.2.2. The chorographic base map

An outline map of the area to be mapped is prepared, with the boundaries of the individual sub-areas clearly shown. Each sub-area is then allocated a unique index number, and this is inserted on to the outline map, in the centre of the appropriate sub-area (figure 3.2.). The choice of a suitable sequence of index numbers may depend to a large extent upon the way in which the bulk of the data for mapping has been collated. In the case of County Durham, for example, the most appropriate sequence was perhaps that employed for most census and official purposes -- viz. alphabetically within County Borough, Urban District and Rural District categories.

The scale of the base map must be consistent with the size of the grid overlay. A base map which is too small may result in a very small and coarse computer map, displaying a marked loss of shape in the outline of individual sub-areas, and a considerable loss of detail in the finished map. On the other hand, one which is too large may necessitate the production of the computer map in two or more separate sections. Besides being more expensive in terms of computer time, the process would also demand a far greater expenditure of time in piecing the individual map sections together. This in itself would defeat the original object of the exercise, which was to reduce the time and effort taken in producing mapped data.

(1) The normal teleprinter carriage width is composed of 130 characters.

Data Composition in the Base Map Matrix for Choroplethic Mapping by Computer

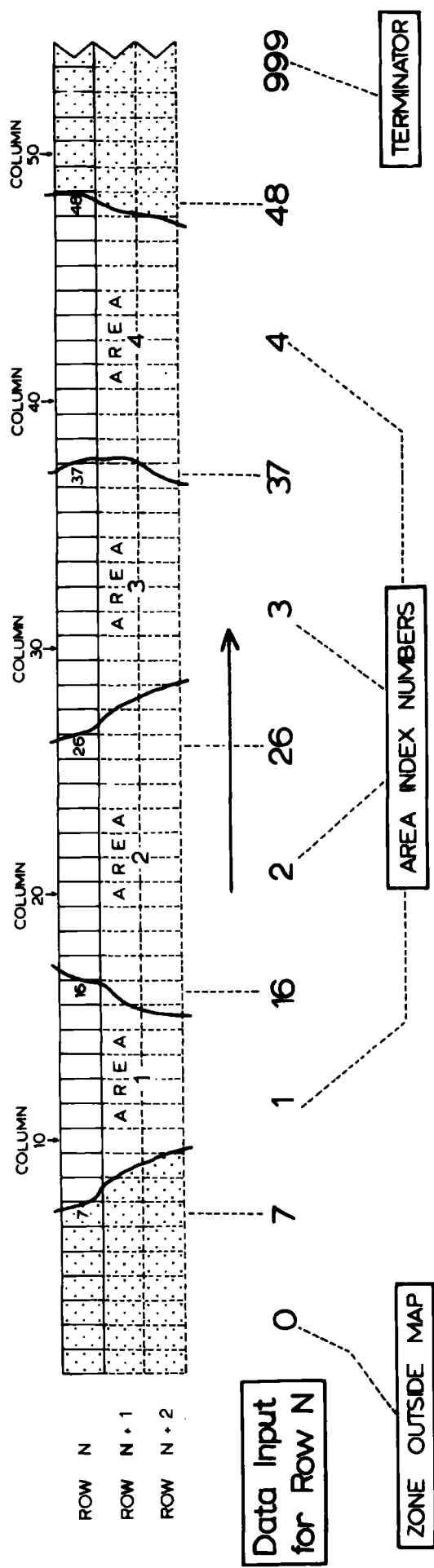


Figure 3.3.

As a rough guide, the original maps of County Durham shown in figures 4.6. to 4.10. were composed of 105 columns and 46 rows of characters, making a total of 4,830 individual grid cells. In this case, the finished computer maps measured 10" x 8", without the trimmings of border and legend.

3.2.3. The basic grid matrix

The construction of the basic grid matrix attempts to define the shape and areal extent of the sub-areas of the map in terms of spatial coordinates.

The gridded overlay is conveniently positioned on top of the chorographic base, and then each grid cell is supplied with the index number of the sub-area over which it is located. For example, in the sample data given in figure 3.3., for row N all the grid cells contained in columns 8-16 inclusive would be allotted the index number 1, referring to sub-area 1; and grid cells from columns 17-26 inclusive would be given the index number 2, and so on. In those areas which are to remain unshaded - i.e. all those areas lying outside the boundary of the base map, or areas representing lakes, rivers and seas - the grid cells are supplied with an index number of zero. Where a boundary between adjacent sub-areas dissects a particular grid cell, the sub-area constituting the greater part of that grid cell takes precedence, and the index number of that sub-area is assigned accordingly to the whole grid cell. At the end of each row, a terminator (arbitrarily fixed as any number in excess of 998) is supplied, immediately following the definition of the final meaningful grid cell which is required to be mapped. The process is then repeated for the next and all subsequent rows of grid cells.

In order to simplify this whole process, the procedure indicated in figure 3.3. has been adopted; whereby only those grid cells which immediately precede boundaries between sub-areas are precisely located

and defined. All the other grid cells in that row are then automatically indexed by the computer programme.

In figure 3.3. the sample data input for row N may be seen to consist of a number of data couplets : the first figure representing the sub-area index number, and the second denoting the column in which that particular sub-area comes to an end. Thus the couplet 0 and 7 signifies that the grid cells of the first seven columns of row N are to be left blank: the following couplet of 1 and 16 indicate that all grid cells from columns 8-16 inclusive are to be supplied with an index number of 1. This process is continued until the terminator is encountered; whereupon the whole procedure is repeated for row N+1, and then for row N+2 and so on, until the grid matrix for the whole map is complete.

Despite the apparent tediousness of constructing the basic grid matrix (as described above); with a little practice, the operation may be accomplished in a remarkably short time period, especially where the individual sub-areas being mapped are large. For example, in the case of the grid matrix for the map of County Durham (used in figures 4.6. to 4.10.), the time taken in preparation was approximately 45 minutes, which was equivalent to the time taken in the preparation of a single chorographic map of the County by conventional methods.

However, once this basic grid matrix has been prepared, it may be utilised over and over again with the MAP programme, to generate any number of different maps of the same area. In each case, all that has to be changed is the data referring to the variable being mapped.

3.2.4. Selection of a suitable variable

Almost any variable may be selected for plotting, provided that a numerical value is available for each of the sub-areas contained within the map. The computer programme is not capable itself of supplying

STMT	LEVEL	NEST	MAP & PROC OPTIONS(MAIN)E	STMT	LEVEL	NEST
1	1		DCL(P,Q,R,M,N,A,Y) FIXED BINE	47	2	1
2	1		DCL(TT) CHAR(50)E	48	2	1
3	1		DCL(XY) FIXED BINE	49	2	1
4	1		OPEN FILE(SYSPRINT) LINESIZE(110)E	50	2	1
5	1		SET LIST(P,Q,R,X)	51	2	1
6	1		GET LIST(INA,NB,NC,ND)E	52	2	1
7	1		SET LIST(TT)E	53	2	1
8	1		GET LIST(XY)E	54	2	1
9	1		REGINE	55	2	1
10	2		DCL(XX) FIXED BINE	56	2	1
11	2		DCL COUNT FIXED BINE	57	2	1
12	2		DCL LOC(TER,TER) FIXED BINE	58	2	1
13	2		DCL DIS(LRP) FIXED BINE	59	2	1
14	2		DCL TITLE CHAR(70)E	60	2	1
15	2		LEGS PROC	61	2	1
16	2		PUT SKIP(21)E	62	2	1
17	3		COLUMN(26),A)E	63	2	2
18	3		PUT SKIP(21)E	64	2	2
19	3		PUT SKIP(21)E	65	2	2
20	3		PUT SKIP(10) EDIT('----- X XXXX',A,COLUMN(28),A,COLUMN(57),A)E	66	2	2
21	3		PUT SKIP(10) EDIT('AAAAA A')(COLUMN(44),A)E	67	2	2
22	3		PUT SKIP(10) EDIT('VVVVV V')(COLUMN(44),A)E	68	2	2
23	3		PUT SKIP(10) EDIT('AAAAA A')(COLUMN(44),A)E	69	2	2
24	3		PUT SKIP(10) EDIT('VVVVV V')(COLUMN(44),A)E	70	2	2
25	3		PUT SKIP(10) EDIT('AAAAA A')(COLUMN(44),A)E	71	2	2
26	3		PUT SKIP(10) EDIT('VVVVV V')(COLUMN(44),A)E	72	2	2
27	3		PUT SKIP(10) EDIT('AAAAA A')(COLUMN(44),A)E	73	2	2
28	3		PUT SKIP(10) EDIT('VVVVV V')(COLUMN(44),A)E	74	2	2
29	3		PUT SKIP(10) EDIT('AAAAA A')(COLUMN(44),A)E	75	2	2
30	3		PUT SKIP(10) EDIT('VVVVV V')(COLUMN(44),A)E	76	2	2
31	3		PUT SKIP(10) EDIT('AAAAA A')(COLUMN(44),A)E	77	2	2
32	3		PUT SKIP(10) EDIT('VVVVV V')(COLUMN(44),A)E	78	2	2
33	3		PUT SKIP(10) EDIT('AAAAA A')(COLUMN(44),A)E	79	2	2
34	2		END LEGS	80	2	1
35	2		LOC = 0E	81	2	1
36	2		DO I = 1 TO 4E	82	2	1
37	2		AX = 1E	83	2	1
38	2		IF Y > 998 THEN DOE	84	2	1
39	2		GOTO EXITE CNDE	85	2	1
40	2		SET LIST(X)E	86	2	1
41	2		DO I1 = XX TO XE	87	2	1
42	2		LOC(I,I1) = YE	88	2	1
43	2		ENDC	89	2	1
44	2		END	90	2	1
45	2			91	2	1
46	2			92	2	1

STMT	LEVEL	NEST	MAP & PROC OPTIONS(MAIN)E	STMT	LEVEL	NEST
148	2	1	GET LIST(XY)E	148	2	1
149	2	1	EXITE ENDE	149	2	1
150	2	1	IF XY > 10 THEN DOE	150	2	1
151	2	1	CALL LEGS ENDE	151	2	1
152	2	1	SET LIST(MM)E	152	2	1
153	2	1	GET LIST(DIS)E	153	2	1
154	2	1	PUT PAGEE	154	2	1
155	2	1	DO IJ = 1 TO (Q+6)E	155	2	1
156	2	1	PUT EDIT('**')(A)E	156	2	1
157	2	1	ENDC	157	2	1
158	2	1	ENDC ENDE	158	2	1
159	2	1	ENDC ENDE	159	2	1
160	2	1	ENDC ENDE	160	2	1

STMT	LEVEL	NEST	MAP & PROC OPTIONS(MAIN)E	STMT	LEVEL	NEST
148	2	1	PUT SKIP EDIT('**')(A)E	148	2	1
149	2	1	PUT SKIP EDIT('**')(COLUMN(2*6),A)E	149	2	1
150	2	1	DO J = 1 TO 4E	150	2	1
151	2	1	PUT EDIT('**')(A)E	151	2	1
152	2	1	DO JJ = 1 TO QE	152	2	1
153	2	1	DO JJ = 1 TO QE IF (2*(LOC(J,J))) < 0 THEN DOE	153	2	1
154	2	1	PUT EDIT('**')(A)E	154	2	1
155	2	1	ENDC	155	2	1
156	2	1	ENDC	156	2	1
157	2	1	ENDC	157	2	1
158	2	1	ENDC	158	2	1
159	2	1	ENDC	159	2	1
160	2	1	ENDC	160	2	1

Figure 3.4.

missing items of data, either by interpolation or any other means.

As a general rule, the values for any given variable should always be positive. The inclusion of negative values induces double shading, or shading of areas which should have remained blank. For this reason, the plotting of deviations from zero, and in particular the mapping of regression residuals, is impracticable, unless there is substantial modification to the basic programme.

In addition, it is important to ensure that the individual values for any given variable are collated in exactly the same logical sequence as noted above in section 3.2.2.

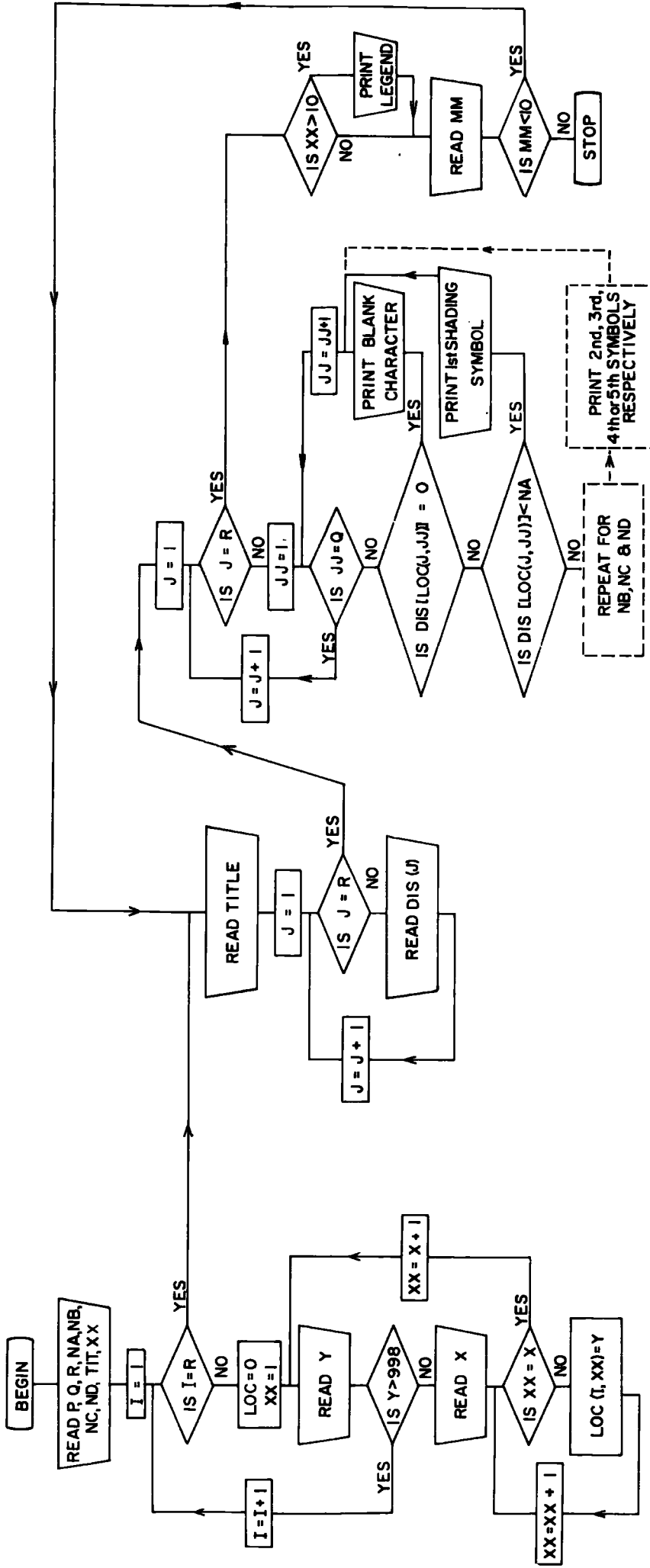
3.2.5. Class intervals

Depending on the nature and range of values to be mapped, suitable class intervals must be determined to ensure an appropriate distributional pattern in the finished computer map. In the present map programme, described herein, a single option of only five class intervals (and shading types) is provided. However, this basic number may be conveniently increased by a slight modification of statement number 7, and the insertion of additional statements immediately following statement number 68 (figure 3.4.). In the case of the computer maps shown in figures 4.6. to 4.10. (inclusive) the full range of 7 shading types are in fact employed.

The five shading types adopted in the present map programme ranged from a solid black symbol - produced by overprinting the characters '0', 'X', 'A' and 'V' - at the upper end of the scale, to a simple '=' character at the lower end. Intermediate shading types were produced by superimposing the character 'X' on top of an '0'; overprinting '-' on an '0', and by printing a simple '0'.

As in the case of conventional choroplethic mapping, the effects of skewness in a particular distribution may be considerably reduced by

FLOW DIAGRAM FOR MAP PROGRAMME



INPUT OF GRID MATRIX

INPUT OF AREAL VALUES
FOR VARIABLE

OUTPUT OF COMPUTER MAP

OUTPUT OF LEGEND

Figure 3.5.

employing a system of octiles or quintiles, or alternatively by selecting appropriate class intervals on the simple arithmetic or geometric scales.

3.3. Programme specifications

A copy of the listing for the MAP programme is given in figure 3.4., and the corresponding flow diagram is shown in figure 3.5. From the latter it may be seen that the programme itself consists of four distinctive steps, which are as follows:-

- i) The input of the basic grid matrix.
- ii) The input of the areal values for the variable to be mapped.
- iii) The output of the computer map.
- iv) The output of the legend for the map (an optional extra).

The map programme is written in PL1 (Programming Language Number 1) and was designed for use on an I.B.M. 360 computer.

3.3.1. Storage requirements

The core storage requirement for the running of the MAP programme is to a large extent dependent upon the size and complexity of the map being produced. In particular, the number of locations comprising the basic grid matrix is of paramount importance. However, since under normal operating conditions a standard I.B.M. 360 machine could be expected to cope with up to half a million items of data, little difficulty should be experienced by the user in practice.

3.3.2. Computation time

The time taken in computation is dependent upon a considerable number of variables associated with the nature of the map being produced. However, generally speaking, the time taken in the actual generation of the map within the computer is relatively small by comparison with that

consumed in the printing out of the finished maps on the line-printer.

The computation phase within the computer is composed of three distinct phases or steps. The first two of these - the compile and link-edit steps - consume a total of only 9 seconds of computer time. During this time the basic programme is read in, interpreted by the computer and set up in readiness for the third step - the 'go-step' - which constitutes the actual execution phase of the programme. The time taken in this final step depends to a great extent on the number of maps being generated at any one time, as well as the dimensions and complexity of the maps themselves. Time taken in computation increases in proportion to the area of the maps being produced, and not simply in terms of the number of lines printed. In the same way, the production of composite shading types is a very time-consuming process, and consequently large areas of heavy shading, necessitating repeated over-printing, may increase the time taken by a factor of three. However, as a rough guide, the following computing times may prove useful:-

<u>Dimensions of the Computer map</u>	<u>Time taken in 'go-step'</u>
3" x 4" map consisting of 8 sub-areas	1.8 secs.
11" x 8" map consisting of 40 sub-areas	5.1 secs.

The output phase by line-printer can vary quite substantially according to the capacity and capabilities of the line-printer being used. However, usually the time taken during this phase may be in the order of ten times greater than that consumed in the actual generation of the maps inside the computer. Thus, whereas a map measuring 11" x 8" may be generated in a matter of 5 seconds within the computer, one or two minutes may be required for the actual printing out of the finished map. For this reason it usually is the time taken in the print-out which is the limiting factor in terms of the work potential for the programme, particularly when a large number of maps are being produced during a single run.

SAMPLE DATA INPUT - FREE FORMAT


DATA SEQUENCE	NOTATION	DESCRIPTION OF DATA
3	P	Number of sub-areas
23	Q	Number of Columns
10	R	Number of Rows
5 10 15 20	NA,NB,NC,ND	Threshold values between class intervals
'PERSONS PER ACRE'	TIT	Variable being mapped (up to 50 characters)
12	XX	Trigger No. to produce a legend at end of map
0 12 1 15 999	 LOC	Basic grid matrix of map (see figure .3) LOC(1:R,1:Q)
0 8 1 17 999		
0 2 2 8 1 18 999		
0 2 2 9 1 20 999		
0 2 2 4 3 8 1 21 999		
0 2 3 8 1 22 999		
0 1 3 9 1 21 999		
3 10 1 22 999		
3 12 1 20 999		
0 3 3 14 1 18 999		
'HOUSING DENSITY'	TITLE	Title of map - (up to 70 characters in length)
6.3 23.6 14.1	DIS(1:P)	Sub area values of variable being mapped
12	MM	{ if less than 10 , recycles programme { if more than 10 , terminates programme

Figure 3.6.

In order to combat the irregular impression of individual characters produced by the average line printer, it may be found preferable to employ a special carbon-lined paper during print out. In this way, a clear and even printing of maps can be obtained.

3.4. Sample data input

Under normal running conditions, the data may be input in a free-format form - that is to say, particular data items do not necessarily have to occupy rigid positions on individual data cards, providing, of course, that they are separated by at least one blank character in each instance. In figure 3.6. the data items have been conveniently divided into a number of discrete sections on individual cards, to assist in the overall comprehension of the sequence.

The example given in figure 3.6. represents the total data input required to generate a single map using the MAP programme. The finished map would contain 3 sub-areas, and would measure 23 columns in width and 10 rows in depth (data cards 1-3). In this particular case, the variable being mapped is 'persons per acre', and the threshold values between class intervals are 5, 10, 15 and 20 persons per acre respectively (data cards 4-5). Card 6 contains a trigger number, which if greater than ten produces a legend and scale at the end of each computer map. However, should this number be less than 10, then these optional extras are suppressed and only the map itself is generated in each case.

The next 10 cards of the data deck constitute the basic grid matrix of the map; the construction of which is described in figure 3.3. and section 3.2.3. above.

Immediately after the basic grid matrix, the title of the first map appears, followed in turn by the individual values for each of the sub-areas. The first map is then printed out together with a legend and scale should this be required by the condition of the initial trigger

factor (card 6). Having reached this point, a second trigger factor (MM) is read in to determine the subsequent course to be followed by the programme. If MM is less than an arbitrary value of 10, then the programme recycles itself by reading a second map title together with a new set of sub-area values. A second map is then generated and output. This recycling process continues until MM is found to be more than 10, whereupon the programme is terminated.

3.5. Conclusion

The major advantage of employing a computer to produce simple choroplethic maps lies in the economies of both time and effort involved in the actual plotting of data values and subsequent line shading. By using a computer, a large number and variety of maps may be generated in the space of a few minutes of actual computer time. This allows the research worker to be selective in the choice of maps to aid his analysis, rather than relying upon a limited number of distributions which he has had time to map by hand.

During the process of computer mapping by lineprinter, a measure of cartographic sophistication inherent in the average hand-drawn map is inevitably lost. Individual boundaries are in the main relatively indistinct and most if not all the constituent sub-areas of the map undergo some form of distortion (or 'rationalisation') in their overall spatial configuration. It is also impossible to introduce as many subtleties of tone in the shading ranges employed, because of the limited number of suitable character combinations available on the average lineprinter type-face.

Notwithstanding the nature of the disadvantages noted above, choroplethic mapping by computer has a valuable contribution to make to geographic research in general, by virtue of the speed at which a considerable volume of data may be conveniently translated into a graphic form which

is readily comprehensible. In the context of the present study, the method was found to have a particular application to the investigation of the more dynamic aspects of disease, including the epidemic spread of measles discussed in chapter 4 below.

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SECTION II

MORBIDITY

"Diseases manifest multiple personalities just as do living creatures and social institutions. The various moods which they display in different circumstances and at any given time reflect the dominant aspect of the relationship between the disease process and the life of man in society."

Rene and Jean Dubos (1953)
The White Plague: Tuberculosis
Man and Society, p.3.

Chapter 4Measles in County Durham 1961-654.1. Introduction

Of the 50 or so viruses already known to produce human disease, the measles virus is by far the most common agent of infection in terms of notifiable disease in England and Wales. However, unlike many of the other viruses, measles appears to accept only man as its natural host, and depends entirely upon transfer from one human being to another. (Taylor and Knowelden 1964:107). Moreover, it would appear that "there is little evidence that measles virus persists on inanimate objects" (ibid:108), which suggests that the reservoir of infection for measles lays entirely within the human host. The mode of transmission of the virus is in the form of a droplet infection derived from the upper respiratory tract. In this way, minute moisture nuclei containing the virus may remain suspended in the air for considerable periods of time. Thus it may be seen that physical proximity of individuals may not necessarily constitute a sine qua non, although in reality this factor is a powerful influence in promoting the necessary quantum of infection to elicit the clinical manifestation of measles.

In their study of the epidemiology of measles, Stocks and Karn (1928) stress the fact that measles is predominantly a disease of childhood, or at any rate in any society where the virus is endemic. A single attack appears to confirm permanent immunity upon an individual, except in about two per cent of cases, where a second or even more attacks are experienced. In the vast majority of cases, the age at which the disease is contracted is associated with the first major

period of communication with other children from outside the immediate family circle. This usually corresponds to the initial entry of a particular child into school or kindergarten. Consequently, it may be seen that in a given neighbourhood it is the school which must ultimately be regarded as the immediate 'reservoir of infection'.

A characteristic feature of the disease is the biennial periodicity of epidemics, a point which is adequately discussed by Stocks and Karn (1928). This particular phenomenon may be explained in terms of the 'quantum theory' propounded by Gill (1928), which rests upon the principle of the balance between the 'infection' and 'immunity' factors of a particular epidemiological situation. In effect the theory postulates that, "a breakdown of quantitative equilibrium between the amount of infective agent being distributed and the communal immunity of the population is the determining factor in epidemic causation." (Stocks and Karn 1928:362). Since a single attack of measles confers virtual immunity for life, it would appear quite obvious that following a major epidemic an adequate time period must necessarily elapse to facilitate the recovery of the population, whereby it is again susceptible to infection by measles. This process of recovery may be achieved in one of two ways; either by the introduction of virgin susceptibles by immigration or birth (Kermack and McKendrick 1927-39) or by the recovery of a large number of individuals, who appear to obtain a 'temporary immunity' to the disease through coming into close contact with the virus during a previous epidemic, without actually contracting the disease itself. In this connection Stocks and Karn point out that "the only explanation which seems possible is that the majority of children intimately exposed to infection who escape contracting measles at the time become immunised, and that such latent immunity gradually disappears" (Stocks and Karn 1929:380).

This process of latent immunity appears to agree favourably with the biennial periodicity concept, in so far as it has been demonstrated that the effect of this temporary immunity appears to wear off after a period of approximately two years.

It would therefore seem possible that the existence of a large reservoir of susceptibles would be a necessary pre-condition for the onset of widespread epidemic conditions. Indeed, Wilson goes so far as to state quite categorically that, "there is no evidence of the epidemicity being determined by atmospheric or similarly widespread conditions. It is probably determined for the most part by the accumulation of susceptible population." (Wilson 1905). However, the author is convinced that whereas this process of accumulation is indeed an important pre-condition for epidemic spread, there must inevitably exist an additional 'trigger factor' to act as the catalyst for epidemicity. It was the search for such a trigger factor that lent added import to the present study.

4.2. Data

4.2.1. Sources

The basic statistics utilised in this study were derived from the weekly returns of births, deaths, infectious diseases and weather (Registrar General) for the period 1961-65 inclusive. Weekly totals of notifications were collated for the five year period for each of the local authority areas of County Durham. For the sake of comparison the weekly totals of notifications for England and Wales were also abstracted at the same time. The data were then punched on to computer cards for subsequent processing.

4.2.2. Limitations of the data

It should be remembered that the data abstracted from the weekly returns represent cases of original notification by general practitioners and others to local authorities during a particular period of seven days. Under these circumstances there are a number of inherent statistical limitations which should be borne in mind.

Firstly there is the chance of inaccuracy developing from the initial diagnosis, since the clinical manifestations of measles may often bear a striking resemblance to those produced by an attack of German measles. Although it is not possible to ascertain the exact number of incorrect diagnoses induced in this way, it is likely that it is relatively small in comparison with the total number of measles notifications. Furthermore, it would appear that by virtue of a certain reciprocity in incorrect diagnosis, the absolute effects of this source of error may indeed be even less. Whereas a number of German measles cases may be notified as measles, the reverse may equally be true.

Non-registration of cases appears to present the greatest potential source of error in the basic data, and a factor for which it is extremely difficult to make allowance during subsequent analysis. The failure to report a clinical case of measles may result from the conscious attempt by the parent or family to conceal the fact of disease within the household. On the other hand a far more likely cause of non-registration may lie with the family doctor who may fail to notify cases to the appropriate local authority. Whereas, measles is notifiable by law under the terms of the Infectious Diseases Act of 1888, many doctors consider that the 2/6d notification fee⁽¹⁾ is not a sufficient inducement to make notification a worthwhile undertaking, particularly

(1) This fee for notification was increased to 5/-d with effect from 1968.

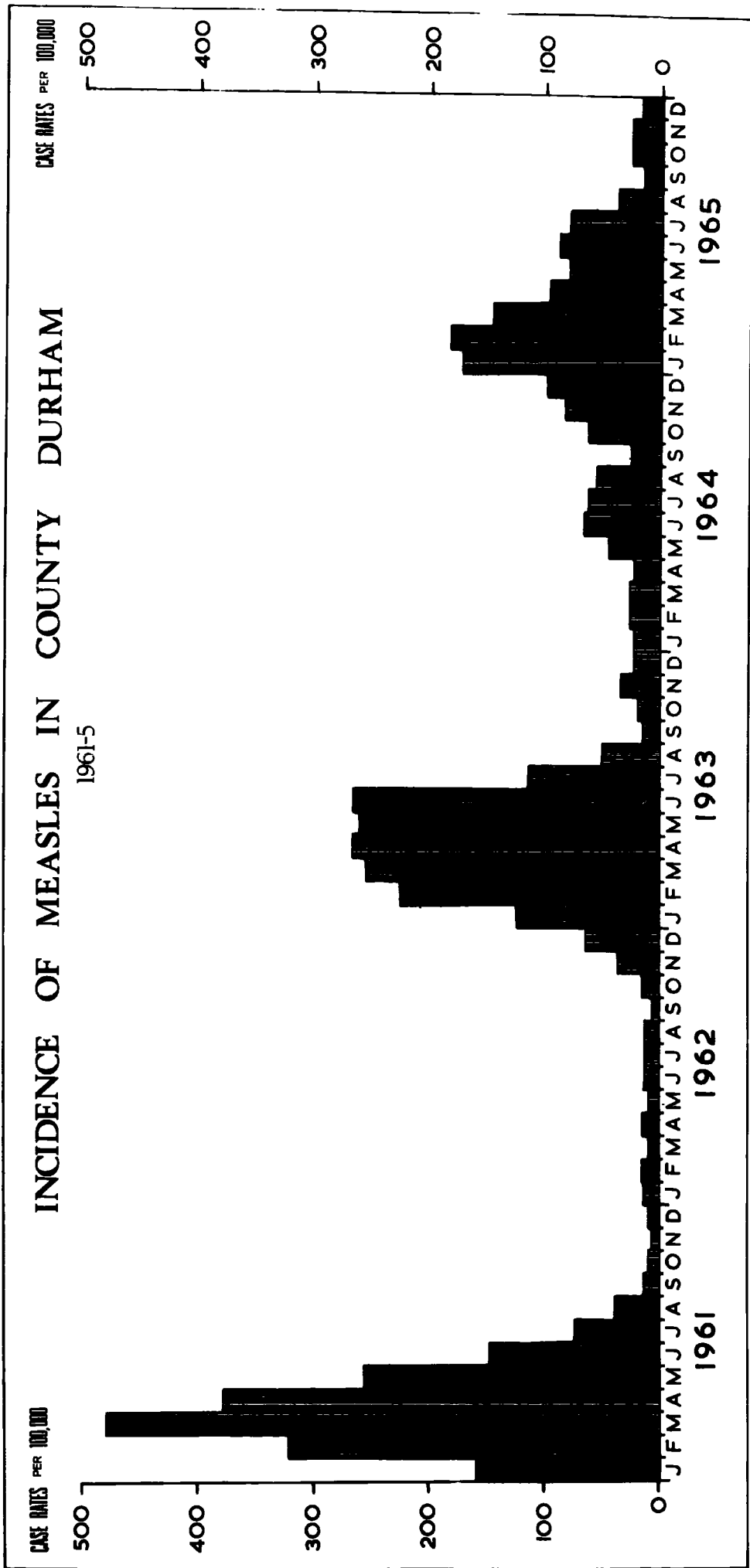


Figure 4.1.

	1961	1962	1963	1964	1965	Total 1961-65	Mean Annual Notication Rate (per 100,000)
County Durham	30,678	3,404	27,346	9,711	16,411	87,550	1154
Darlington C.B.	1,720	48	1,210	660	529	4,167	990
Gateshead C.B.	2,723	254	2,107	876	1,140	7,100	1,375
South Shields C.B.	2,061	462	2,040	811	1,149	6,523	1,187
Sunderland C.B.	4,653	199	4,106	1,684	1,847	12,489	1,317
West Hartlepool C.B.	1,051	18	1,232	280	717	3,295	855
Barnard Castle U.D.	211	82	12	72	320	697	1,647
Billingham U.D.	180	244	407	333	350	1,514	736
Bishop Auckland U.D.	652	155	678	357	778	2,580	1,419
Blaydon U.D.	552	7	419	71	344	1,393	906
Boldon U.D.	355	42	278	160	98	933	818
Brandon U.D.	506	107	481	136	211	1,441	1,451
Chester-le-Street U.D.	281	6	275	47	148	757	798
Consett U.D.	841	13	796	52	524	2,226	1,143
Crook U.D.	510	129	175	379	249	1,442	1,143
Durham M.B.	372	43	304	48	206	973	936
Felling U.D.	1,350	16	813	172	332	2,683	1,475
Hartlepool M.B.	325	-	467	110	207	1,109	1,255
Hebburn U.D.	876	238	290	268	217	1,889	1,514
Hetton-le-Hole U.D.	465	-	144	31	106	746	854
Houghton-le-Spring U.D.	658	43	560	48	545	1,854	1,206
Jarrow M.B.	798	118	609	234	292	2,051	1,428
Ryton U.D.	304	-	239	8	163	714	1,032
Seaham U.D.	572	13	695	243	147	1,670	1,177
Sildon U.D.	142	11	413	92	211	869	938
Spennymoor U.D.	207	225	276	97	343	1,148	842
Stanley U.D.	676	33	1,010	54	491	2,264	766
Stockton M.B. —	1,090	202	1,130	511	670	3,603	887
Tow Law U.D.	77	51	47	2	12	189	1,292
Washington U.D.	609	32	393	20	364	1,418	1,381
Whickham U.D.	646	27	533	110	427	1,743	1,371
Barnard Castle R.D.	414	67	338	88	214	1,121	1,317
Chester-le-Street R.D.	676	23	479	102	652	1,932	938
Darlington R.D.	401	3	719	132	281	1,536	1,288
Durham R.D.	506	121	525	121	445	1,718	980
Easington R.D.	1,620	35	2,030	481	930	5,096	1,196
Lanchester R.D.	288	98	319	18	155	878	1,202
Sedgefield R.D.	581	35	430	133	153	1,332	722
Stockton R.D.	34	76	65	54	36	265	546
Sunderland R.D.	614	161	280	570	113	1,738	1,225
Weardale R.D.	89	7	27	40	291	454	1,072

Table 4.1. Notifications of Measles in County Durham 1961-65.

in the case of a relatively trivial childhood disease such as measles. Furthermore there may be the additional source of error introduced as a result of the late notification of cases. This can often produce an unrepresentative skew in the temporal pattern of incidence, particularly in the more remote rural areas where general practitioners may notify cases of measles to the local health authority up to a week or so after the actual onset and diagnosis of disease.

4.2.3. Initial data processing

A simple computer programme was devised to convert the weekly notifications of measles to weekly notification rates for the five year period under consideration. The population figures for the 1961 census returns were applied to the weekly totals of notifications to yield notification rates per 100,000 persons, for each of the 40 local authority areas within the County.

However, it soon became apparent that the use of weekly statistics would prove completely inappropriate for the purposes of mapping, since — only a small number of cases were notified per week, except during periods of widespread epidemicity. Under these circumstances, it was decided to compound the weekly totals to produce monthly case rates, thereby hopefully reducing the effects of chance fluctuations induced by small samples. For this purpose, individual weekly returns were assigned to an appropriate calendar month on the basis of their 'terminal date'. That is to say, a particular return 'for the week ending March 1st 1963', would be included in the monthly total for March, despite the fact that six out of the seven days in that week related to notifications recorded during the previous month. To facilitate general comparability between monthly case rates, the concept of a 'standardised four week month' was adopted. Any month being assigned five weekly returns had its absolute number of notifications for the

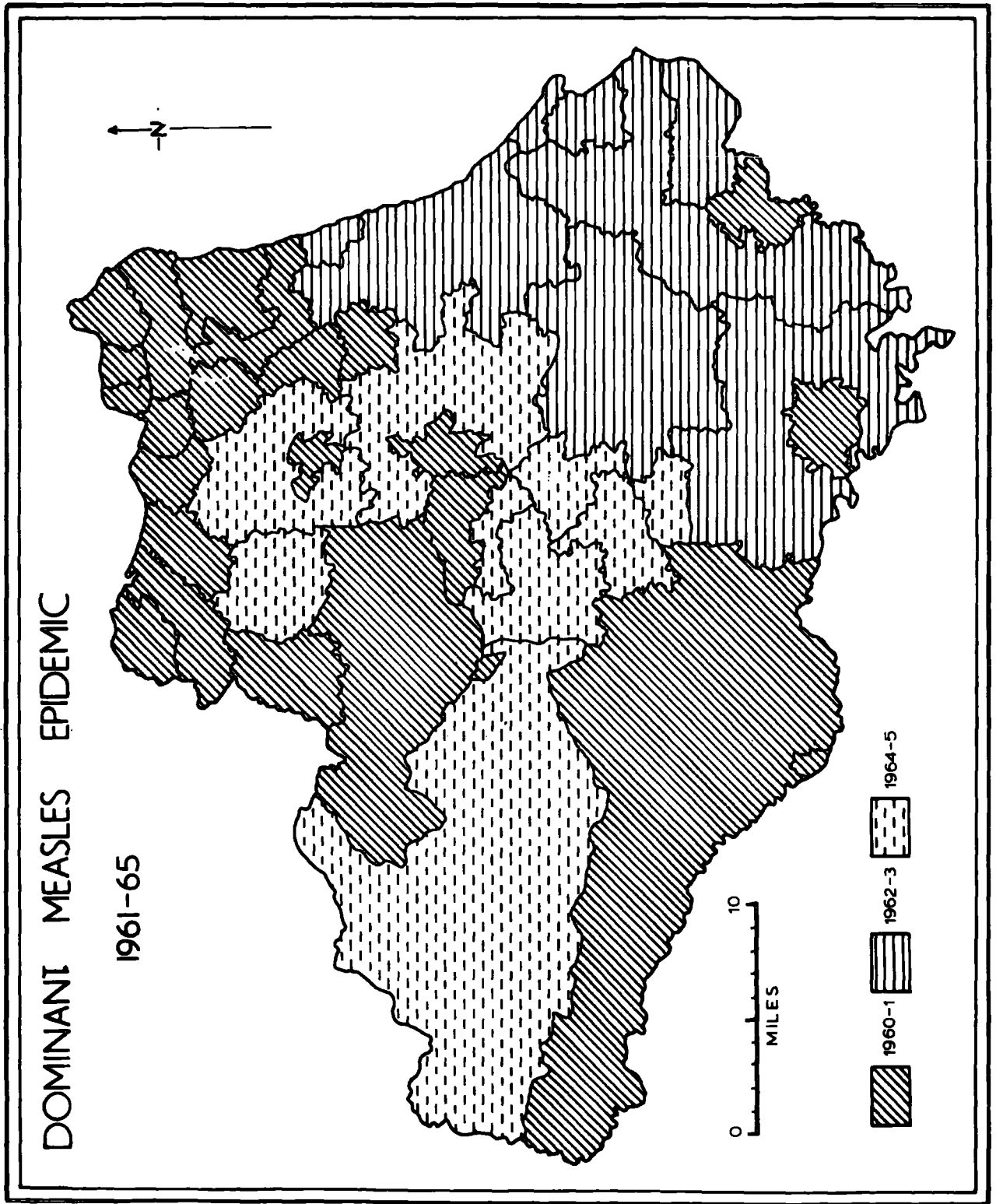


Figure 4.2.

month reduced by a factor of $\frac{4}{5}$. Appropriate notification rates were then recalculated on the basis of the 'standardised four week month' for each of the 40 local authorities. By applying these standardised data to the computer mapping programme described in chapter 2 above, a series of 60 maps of monthly notification rates for measles was obtained (figures 4.6. to 4.10. inclusive).

4.3. Epidemic regimes within County Durham

The epidemic regime for measles in County Durham appears to concur extremely closely with the observations of previous workers in this field, notably Wilson (1905) and Stocks and Karn (1928). Figure 4.1. clearly demonstrates the characteristic biennial cycle for measles epidemics. However, during the five year period there appeared to be two distinctive trends taking place with respect to the regimes of individual epidemic peaks. Firstly, the notification rates for the peak month of the epidemic declined dramatically from 500 per 100,000 for the 1961 epidemic to less than 200 per 100,000 during the 1964-65 epidemic period. Secondly, the epidemic periods themselves appeared to be getting progressively wider-based. That is to say epidemic conditions prevailed for a far longer time span, thereby reducing the inter-epidemic period. With only three epidemic periods under consideration, it is clearly unwise to draw more than tentative conclusions from these trends although there are a number of influences which could be invoked to explain these changes. In particular, there is the possibility that the increasing application of inoculation amongst schoolchildren could well be producing such effects in the overall pattern of notifications. With the increasing percentage of 'artificial immunes' in the population, an inherent impedence to the passage of infection through the community would be introduced, thereby promoting a far more ahrhythmic transmission of the disease. At the same time,

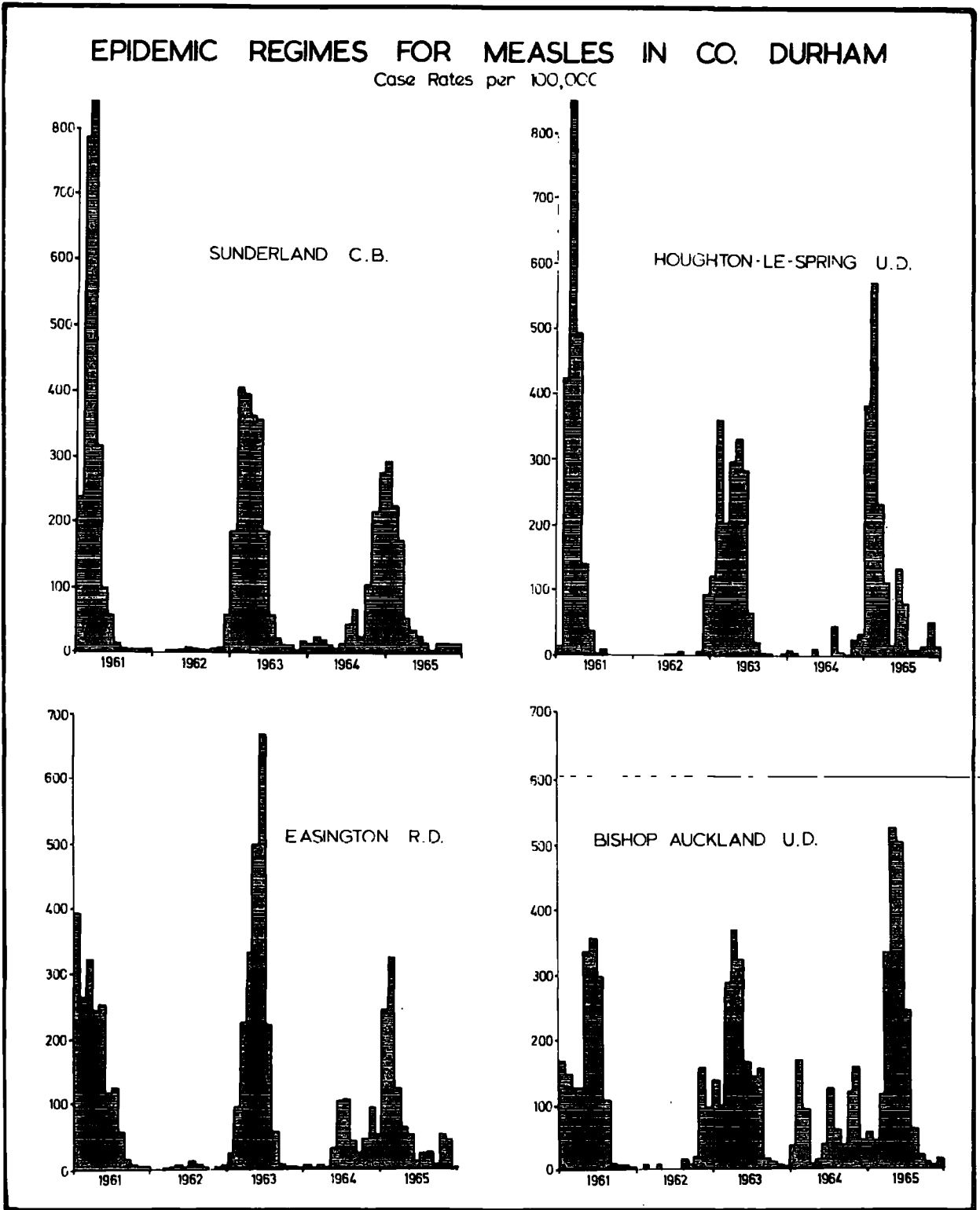


Figure 4.3.

the removal of susceptibles from the population at risk, by means of inoculation, would inevitably reduce the absolute size of subsequent epidemics.

On the other hand it might be argued that the trends noted in the epidemic regimes for County Durham may merely reflect a stage in a much longer-term cycle which may also be regarded as characteristic of the disease. Wilson (1905:80) in his paper entitled "Measles: its prevalence and mortality", suggests that apart from the biennial trend, there is also "a periodicity among the epidemic years themselves, indicated by a rise at every third epidemic." In addition, there is also a suggestion of a still wider cyclical change spanning a period of between twelve and fifteen years.

When a more detailed study was made of the epidemic regimes for individual local authority areas, it was discovered that the situation was not nearly so simple as at first imagined. Indeed, in many cases the 1962-63 and/or the 1964-65 epidemic waves exhibited a substantially higher peak monthly incidence than the first epidemic season of 1961. As a result, a comparative study was undertaken by mapping the dominant epidemic season for each local authority as indicated by the peak month notification rate in each case (figure 4.2.)⁽¹⁾ At the same time a number of epidemic regimes were constructed for selected local authorities to demonstrate both the nature and the extent of this variation (figure 4.3.).

From figure 4.2. it may be seen that the County divides itself into three distinctive zones, each of which exhibits a different dominant epidemic cycle. In Wearside, Tyneside and north-west Durham

(1) However, it must be borne in mind that the "highest peak in an epidemic does not always indicate the extent or mass of the epidemic. Some epidemics rise quickly to a great height, and fall as quickly, while others, which do not rise so high, cover a longer period of time." (Wilson 1905:67).

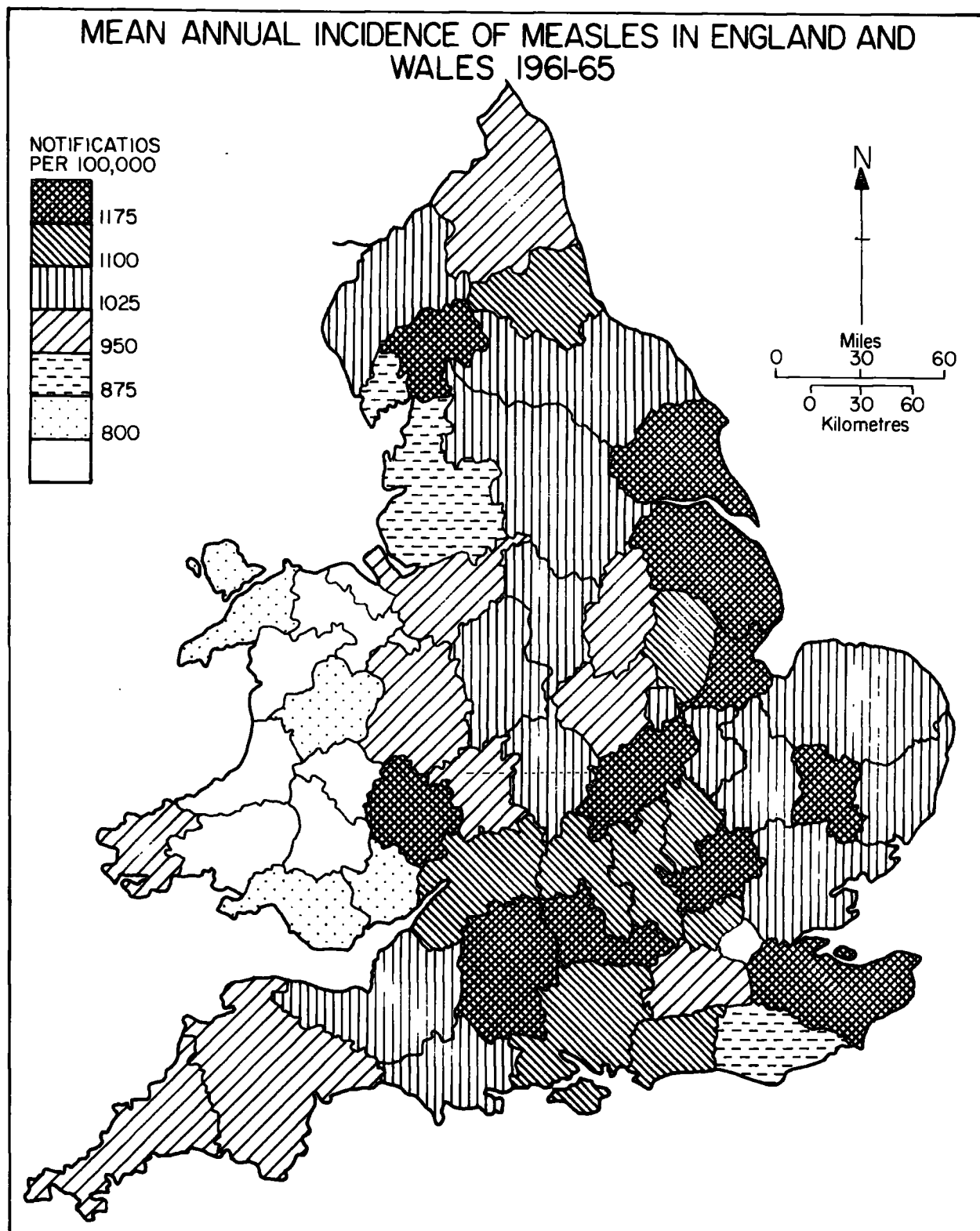


Figure 4.4.

(with the exception of the urban district of Stanley) the 1961 wave was clearly the dominant epidemic cycle, thereby reflecting the regime for the County as a whole (figure 4.1.). Sunderland C.B. (figure 4.3.) was selected as exhibiting a typical regime of this type. The south-east of the County, extending from Seaham to Darlington R.D., could be distinguished as the second zone, in which the 1962-63 epidemic was dominant. In this case the rural district of Easington was selected as representative. The notable exceptions to this second consolidated zone were provided by Darlington C.B. and Stockton M.B. in which the 1961 epidemic was clearly dominant. This also applied to the sparsely-populated south-western area of the County comprising the urban and rural districts of Barnard Castle.

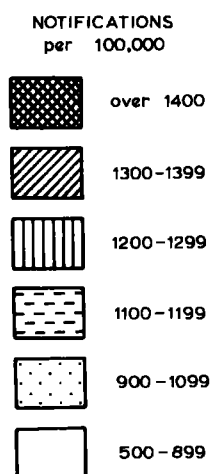
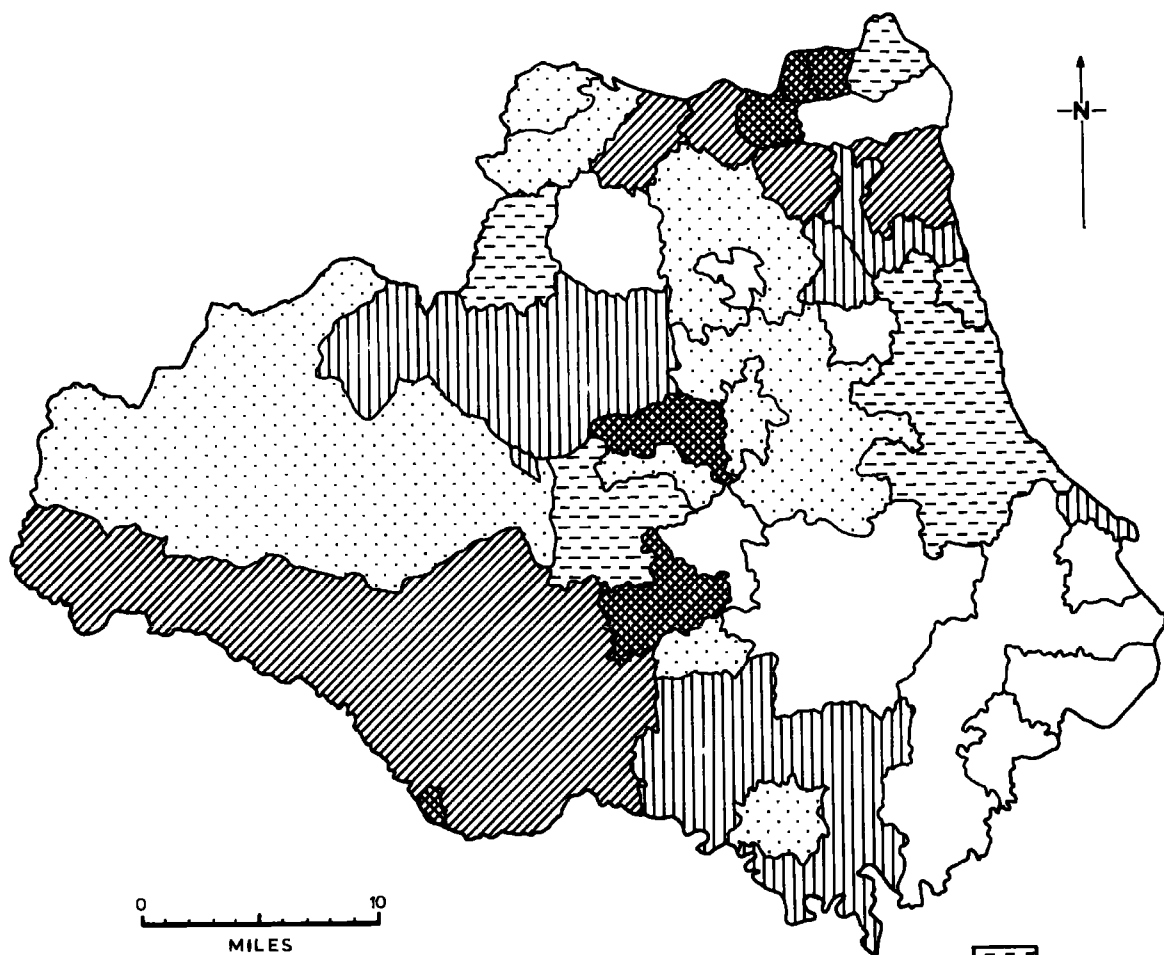
The third and final zone, centred upon the cluster of urban districts of south-west Durham and incorporating the rural districts of Durham, Chester-le-Street and Weardale, recorded the 1964-65 cycle as the dominant epidemic wave. Bishop Auckland may be deemed typical of this type of regime. However, in this case the degree of dominance was not nearly so well-defined as in the other two zones noted above. Moreover, it was noted that at the boundaries between each of these three major zones, there appeared to be a tendency for local authorities to adopt a composite regime. For example, in the case of Houghton-le-Spring (figure 4.3.) although the 1961 cycle was clearly dominant, the third epidemic cycle 1964-65 occupied the second position, thereby reflecting the area's proximity to the zone dominated by the third epidemic cycle.


4.4. The spatial distribution of measles

4.4.1. The national situation

Figure 4.4. provides an overall picture of measles incidence in England and Wales during the period 1961-65. Quite obviously in the

MEAN ANNUAL INCIDENCE OF MEASLES
COUNTY DURHAM 1961-65



 = 1,000 Persons

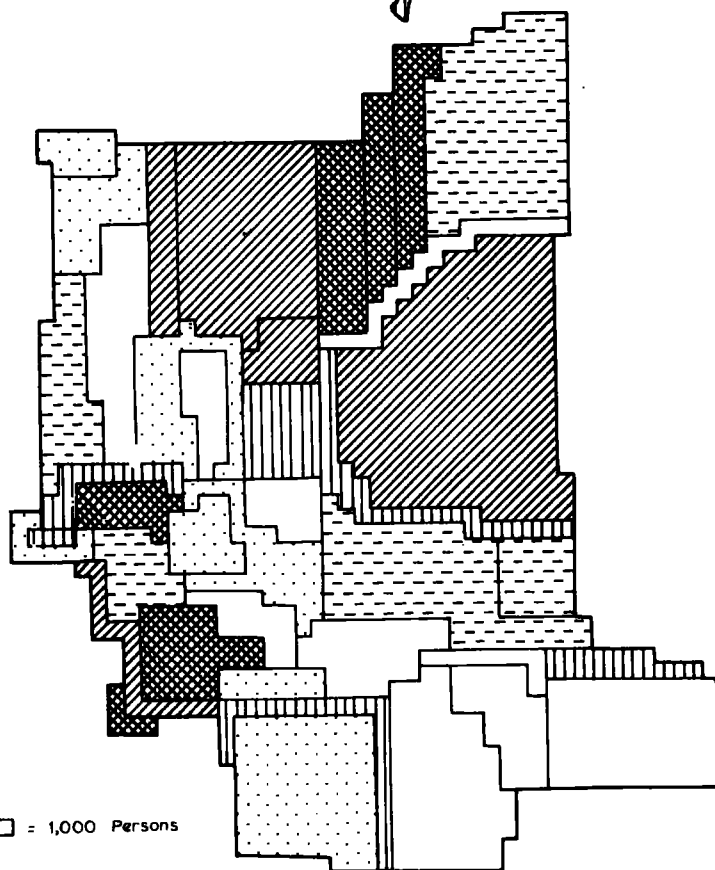


Figure 4.5.

case of an epidemic disease such as measles it would not be wise to place too much emphasis upon the interpretation of a map constructed for such a protracted time period. Nevertheless, it is perhaps interesting to note the appearance of an extensive area of high incidence in south-central England which approximates to the demographic centre of the country. In contrast, the more remote and less populous districts of Wales constitute a consolidated area of low notification rates. County Durham, whilst not outstanding in terms of its absolute notification rates, does however emerge as a significant area of high incidence, bearing in mind its relative importance in demographic terms.

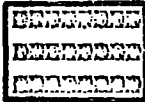

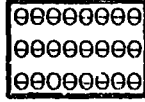
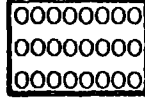
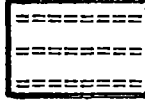
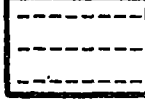

4.4.2. County Durham

During the period 1961-65 just over 87,500 cases of measles were notified for County Durham and its associated county boroughs, yielding a mean annual notification rate of 1,154 per 100,000. Figure 4.5. shows the spatial distribution of mean annual notification rates by local authority for the five year period. It is interesting to note that there was in fact as much variation in incidence within the County as had been noted for England and Wales as a whole (figure 4.4. and table 4.1.). Two distinct areas of high notification rates emerge from the map. The first of these, located in South Tyneside, centred on the urban districts of Felling, Hebburn and Jarrow, and extending south into Wearside, is by far the more significant at least in demographic terms. Furthermore, as will be shown later this is the area which appears to act as the gathering ground for infection before an epidemic occurs. Secondly, there is a less well-defined area of high notification rates to the south-west of the County, centred on Brandon and Bishop Auckland, and extending towards Barnard Castle. Although perhaps not particularly important in terms of the absolute number of cases recorded, it is

Figures 4.6. to 4.10

Monthly notification rates for measles in County Durham
1961-65 (per 100,000).

LEGEND

	Over 640
	320 - 639
	160 - 319
	80 - 159
	40 - 79
	20 - 39
	Under 20.

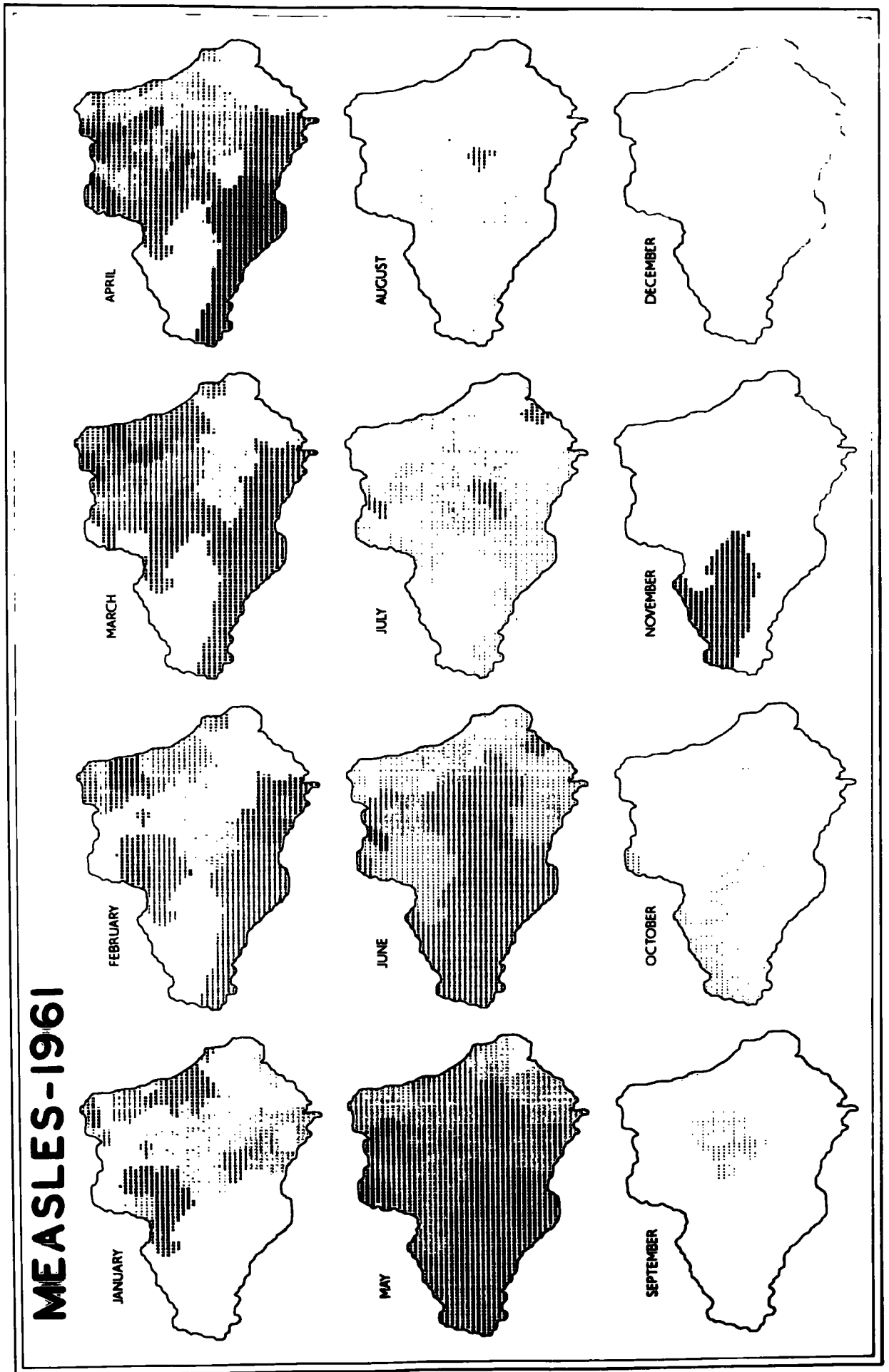


Figure 4.6.

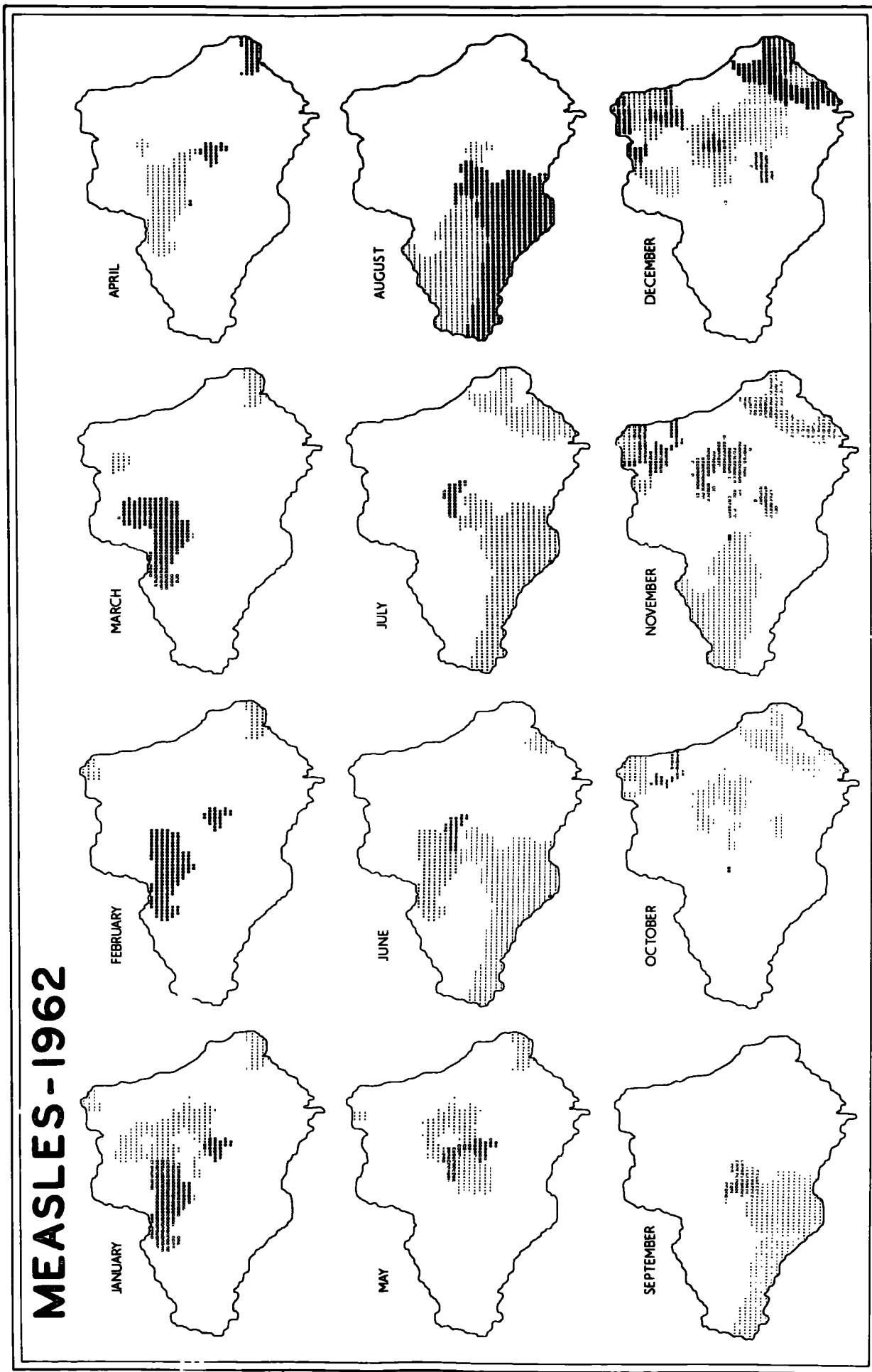


Figure 4.7.

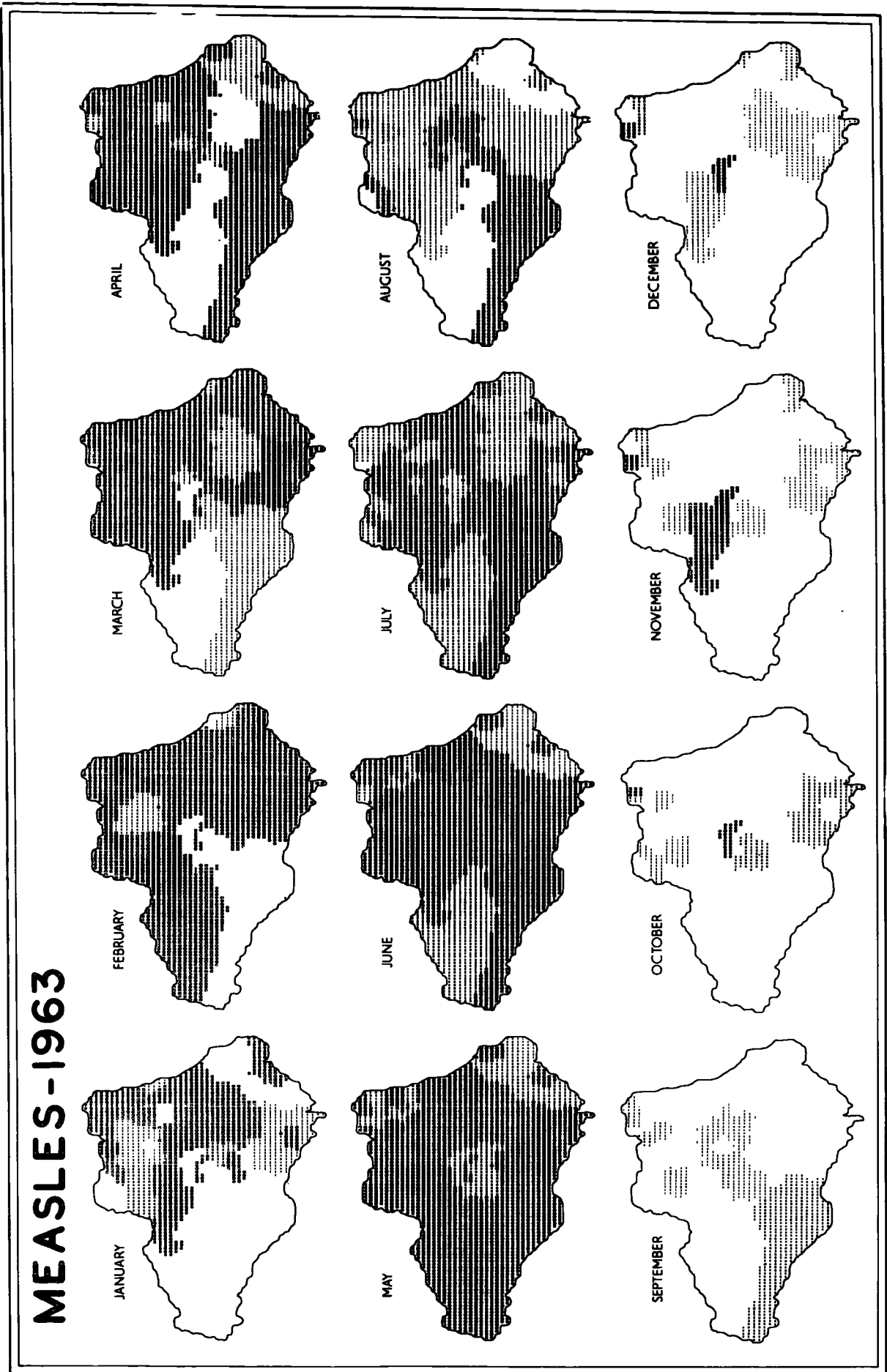


Figure 4.8.

MEASLES - 1964

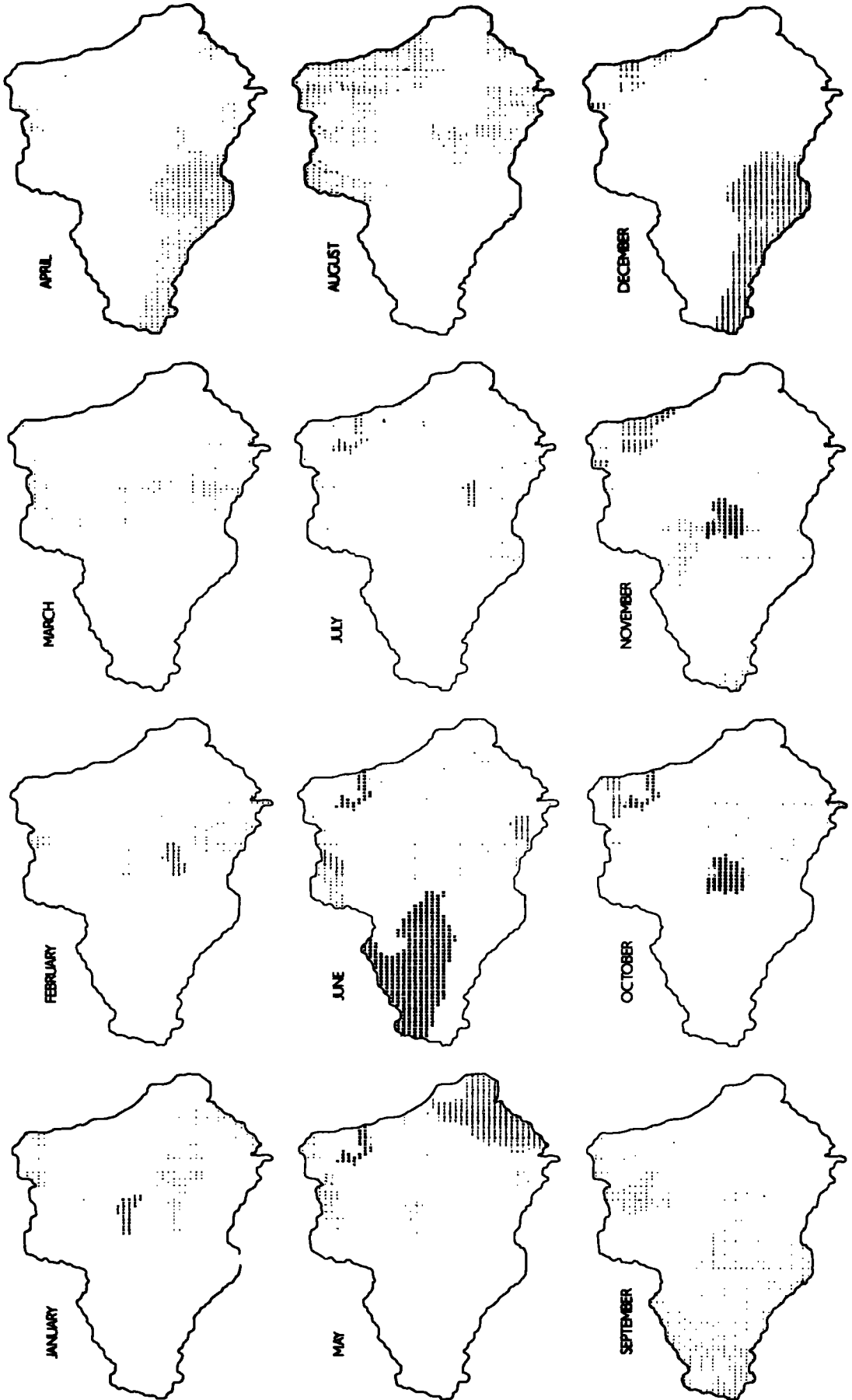


Figure 4.9.

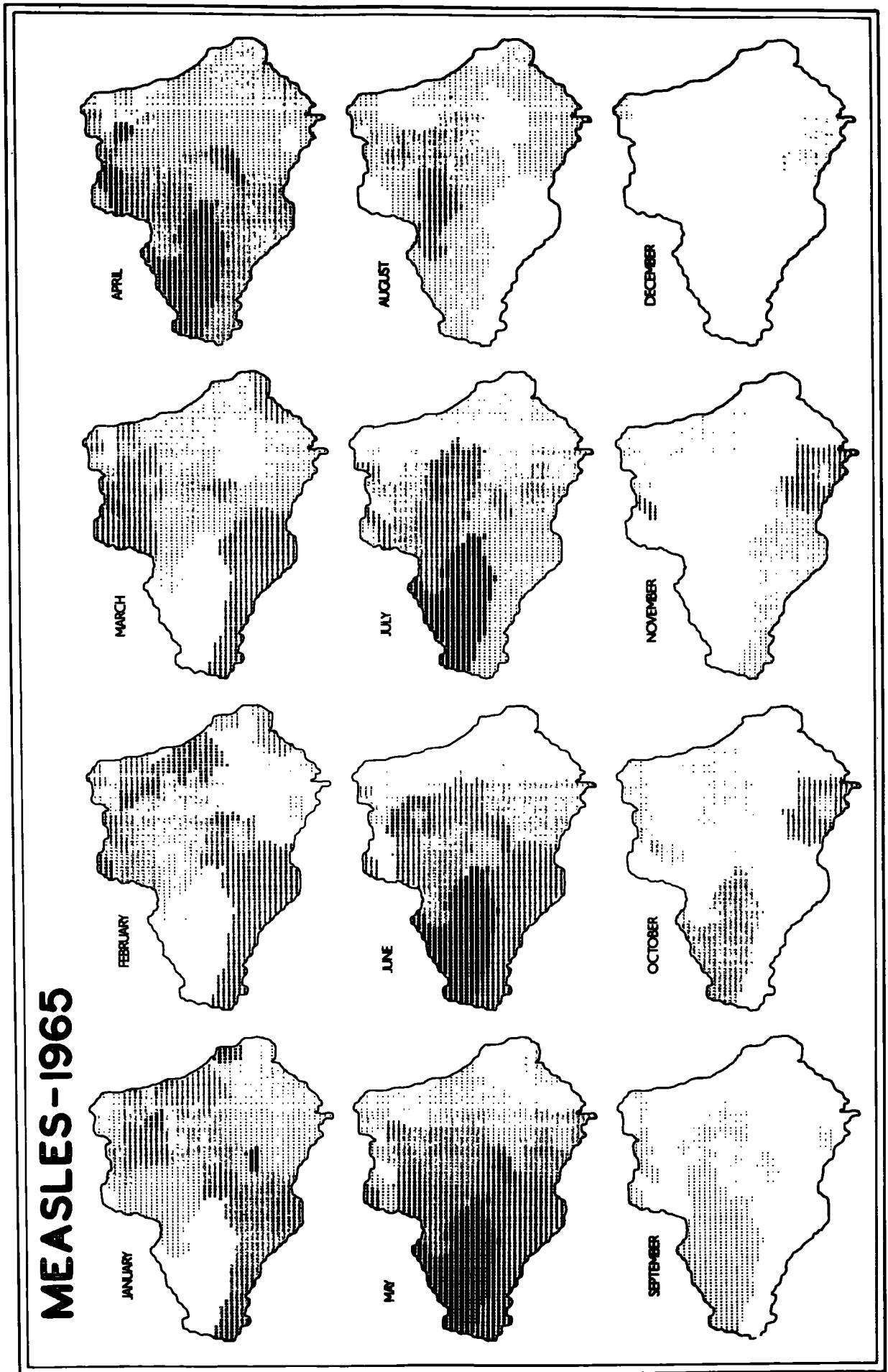


Figure 4.10.

nevertheless extremely important from an epidemiological point of view, since it would appear that it is here that the infection tends to smoulder during the long inter-epidemic periods.

In complete contrast there is a consolidated area of low incidence to the south-east of the County, incorporating north Teesside, West Hartlepool and the rural districts of Sedgfield and Stockton. In this case, recorded notification rates were up to 50% less than in south Tyneside. The remainder of the County, including much of central and north-west Durham, recorded moderate to low values. However, in this case, it was not possible to discern any marked pattern or trend in the distribution of incidence.

As an initial step in the investigation of epidemic spread the monthly notification rates were mapped, using the computer mapping programme (see chapter 3 above) producing a series of 60 chorographic distribution maps for the disease (figures 4.6. to 4.10.). From a merely cursory examination of this sequence of maps it was possible to distinguish quite clearly the three major periods of epidemic activity already suggested by figure 4.1. It was also possible to recognise the existence of a number of distinctive focal points from which the measles virus appeared to be disseminated during times of epidemicity. These localities were usually first to experience a distinctive rise, or 'onset', of the disease. Moreover, these foci were generally found to experience a more prolonged period of epidemic activity than other parts of the County.

At the same time, it was possible in certain cases to trace the apparent dissemination of infection itself between adjacent local authorities from one month to another, thereby suggesting the existence of well-defined pathways of epidemic spread.

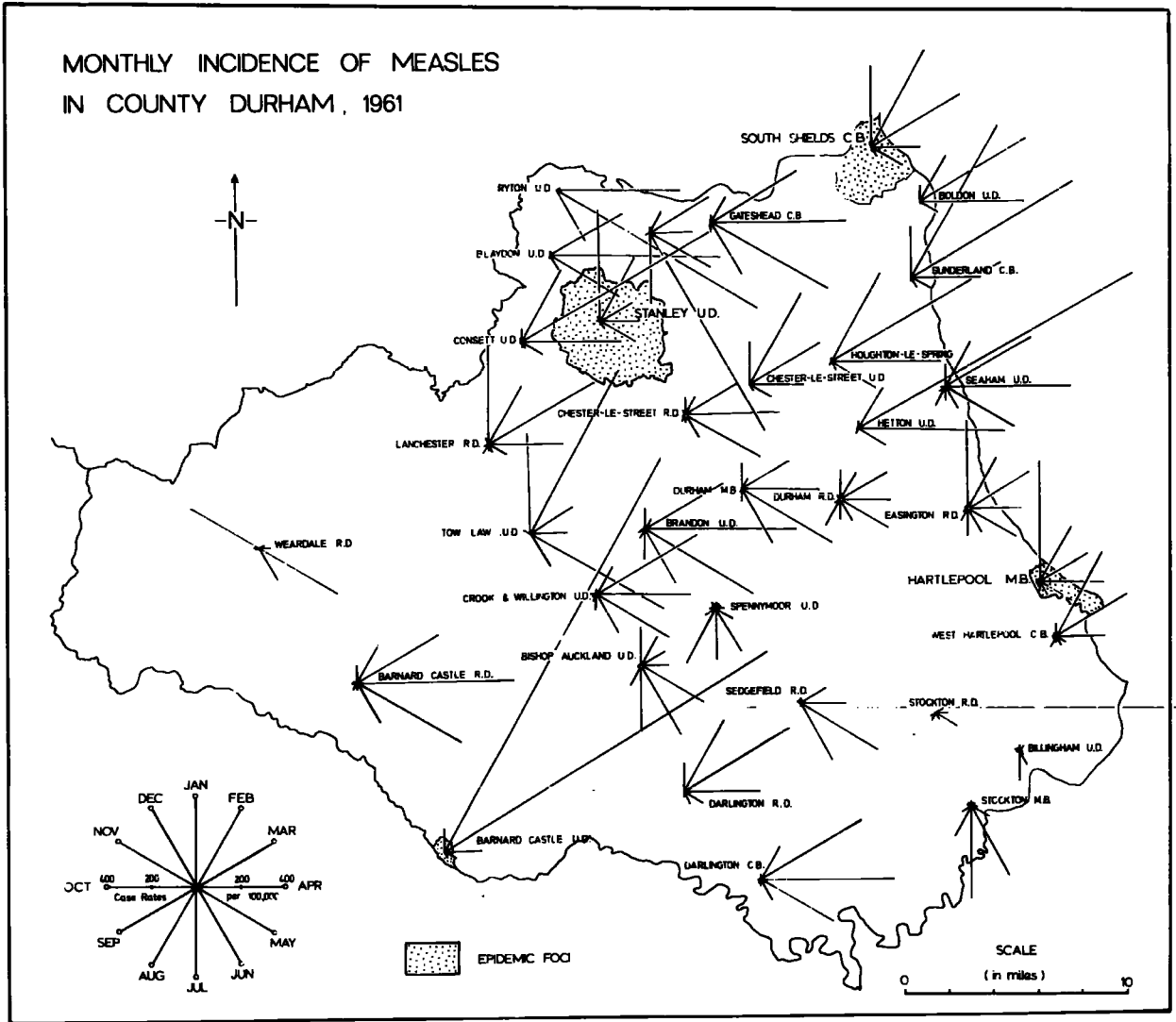


Figure 4.11.

4.4.2.1. The 1961 epidemic

In the case of the first epidemic wave, the calendar year of 1961 was arbitrarily adopted as the time period for investigation, despite the fact that conditions of widespread epidemicity were largely confined to the first half of the year.

An initial perusal of the monthly case rates and figure 4.6. revealed that the advanced signs of epidemicity were already manifest by the January of the year. By that stage, South Shields C.B., Stanley and Hartlepool had monthly notification rates in excess of 320 per 100,000. These three local authorities, together with the relatively isolated urban district of Barnard Castle - which literally 'exploded' into epidemic activity during February - were selected as the primary epidemic foci, from which the infection spread out into surrounding areas. The high January case rates for Easington R.D. and Jarrow M.B. were explained in terms of their proximity to the primary foci of Hartlepool and South Shields respectively.

Having postulated the four primary foci of epidemicity, this hypothesis was tested by a comparative study of the individual epidemic regimes for the other local authority areas within County Durham. This was achieved with the aid of figure 4.11., a simple application of the 'wind rose' principle. At the outset, it must be stated that this application of this technique is quite experimental in an epidemiological context. As such the measure of success which has been achieved must be gauged objectively by the reader. Nevertheless, several interesting points do emerge from a closer examination of this particular cartogram.

Firstly, with the exception of small nucleated settlements such as Tow Law and Barnard Castle, there appeared to be a gradual diminution in total incidence of measles, from north to south, particularly in the eastern half of the County. Secondly, the areal differentiation of the

individual epidemic regimes tended to support the four foci hypothesis, in so far as the adjacent areas to the foci experienced a relatively early peak month, as compared with more remote authorities. Thus in the case of Barnard Castle, a steady migration of infection can be discerned: the peak month occurring in Darlington R.D. in March; Barnard Castle R.D. and Darlington C.B. in April; and finally Weardale in May.

In the case of the more remote areas - 'remote' in the sense of being removed from the epidemic foci - north Teesside and south-west Durham proved to be of particular epidemiological interest. In both cases, the origin of the infection appeared from the cartographic evidence to have been the northern foci of Stanley and South Shields respectively. For this reason the arrival of the epidemic peak appears to have been retarded in both cases; occurring during May in the rural districts of Sedgfield and Stockton; June at Bishop Auckland; July at Stockton M.B. and Billingham; and finally during August at Spennymoor. It is perhaps interesting to note that this situation is at variance with the findings of Wilson (1905:68) who states that although the month of peak epidemicity could vary quite significantly, in particular localities from year to year, the months of July and August did not appear to support such epidemic conditions.

Since for the purposes of primary analysis, figure 4.11. was deemed to be rather complex, the fundamental elements of epidemic spread during the year were subsequently investigated by means of the 'centre of gravity' principle; a method which had been successfully applied to the study of the spread of influenza in England and Wales during the epidemic of 1957 (Hunter and Young, 1969). Initially the centroidal

coordinates⁽¹⁾ were calculated on a weekly basis, and then plotted on to a suitable chorographic base map. However, because of the statistical insignificance of the weekly figures, particularly during the latter half of the year, the resultant centrogram pattern was so haphazard and complex that further analysis at this level was deemed inappropriate. Accordingly, the situation was rationalised to the analysis of a centroidal pattern based on a series of consecutive five week periods (figure 4.12.). From this map it may be seen how, by the beginning of the year, the centroid had already migrated to the north of the County, in response to the build up of infection in Tyneside, particularly in South Shields and Jarrow. The subsequent dissemination of the virus from these focal or 'reservoir' areas is reflected in a corresponding westerly shift in the position of the centroid during the next three time periods, representing the development of epidemic conditions over much of north and west Durham.

During periods 5-7, the translation of the centroid occurred in a predominantly southerly direction, although incorporating a significant easterly component. This was indicative of the fact that the northern areas had already undergone the major part of their epidemic regime, which facilitated the relative rise to dominance of the central and south-eastern areas of the county. During the last four time periods (8-11) the centroid continued to migrate quite substantially, particularly between periods 9 and 10. However, bearing in mind the relatively small number of measles cases recorded towards the end of an epidemic period, it would appear that the location of the centroid is

(1) A centroid, or centre of gravity, may be defined as that point at which a given spatial distribution would balance, if each individual of the distribution were considered to have the same mass; thereby exerting a force proportional to its distance away from the central point. As such, the centroid may only be considered a rather crude index of geographical shift.

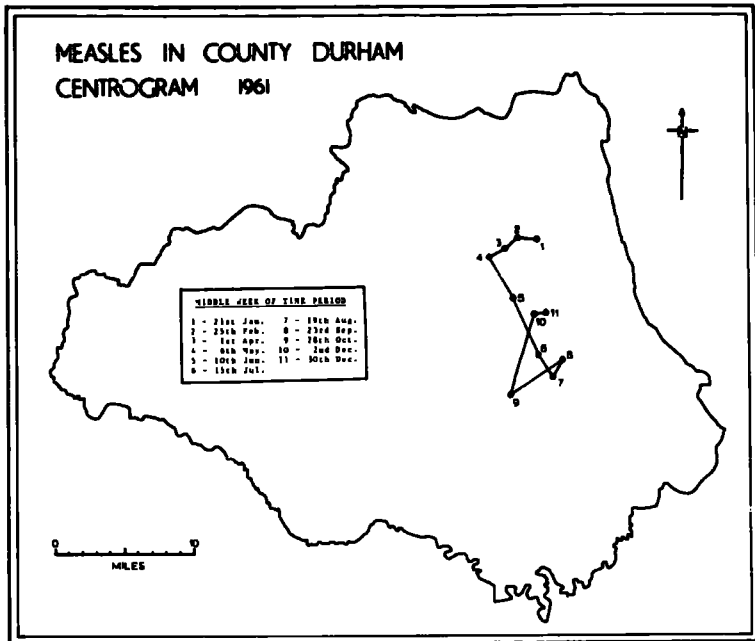


Figure 4.12.

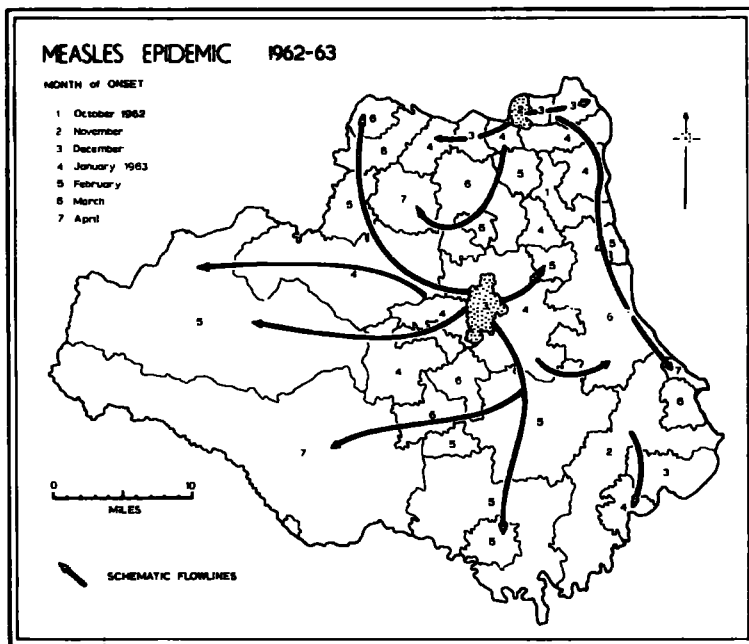


Figure 4.13.

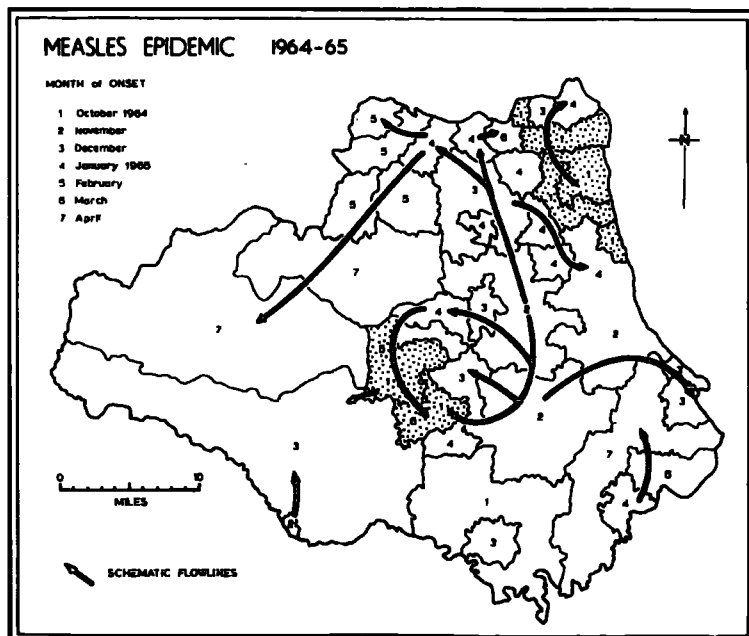


Figure 4.14.

determined to an increasing extent by chance fluctuation in the data. Consequently, all that may be said of this period is that, in all probability, there was a tendency for the centroid to re-establish itself in a position of relative spatial equilibrium.

4.4.2.2. The 1962-3 Epidemic

Although this second epidemic period did not achieve the same intensity as the first - gauged by the peak month incidence (figure 4.1.) - the overall number of notifications was in fact very similar, at approximately 30,000. In this case the epidemic season was regarded as extending from October 1962 to September 1963.

An examination of the maps of monthly notification rates for the period (figures 4.7. and 4.8.) suggested a fairly well-defined pattern of epidemic spread. This situation was rationalised by constructing a map showing the month of onset of epidemic conditions by local authority (figure 4.13.). This is analysed in some detail below.

Apart from the somewhat anomalous early onset recorded for Sunderland rural district, there appeared to be three separate foci of infection within the County. The most important one of these, in terms of the absolute number of cases involved, was located in south-east Tyneside, and centred on the urban district of Hebburn which recorded an epidemic rise as early as November 1962. It seems likely that dissemination of the virus took place from this focus into the rest of Tyneside and also southwards along the Durham coast as far as The Hartlepoons.

The second focal area, centred on Durham City, appears to have produced a far more significant spatial dissemination of the disease. Indeed, in all probability, its sphere of influence extended to Ryton in the north-west of Durham, Weardale in the west and to Darlington in the south. The third and final area, exhibiting a particularly early onset, was Stockton R.D. (November 1962). However, in this case,

the schematic flow lines for the area indicate that its influence would appear to have been restricted to the immediate environs of Teesside.

The remarkable differences in month of onset between one part of the county and another in the 1962-63 epidemic may help to explain in part the varying epidemic regimes noted in section 4.3. above. Thus in the south-east of the county, a relatively late onset provided an appreciably longer period for the recruitment or the replacement of susceptibles and also the waning of the temporary immunity factor; thereby facilitating a correspondingly greater intensity of epidemic activity. For example, in the case of Easington with a 30 month interval between epidemic peaks, an overall notification rate of 1,850 per 100,000 was recorded for the five principal epidemic months (March to July 1963). This compared with a notification rate of only 1,254 for Hebburn (November 1962 to March 1963) with only a 20 month interval between epidemics.

4.4.2.3. The 1964-65 Epidemic

Figure 4.1. indicates that the 1964-65 epidemic season was composed of two distinct elements: a) a pre-epidemic rise from May to August 1964 and b) the major epidemic period from October 1964 to August 1965. For the purposes of the present investigation of spatial dissemination, the pre-epidemic rise was omitted, and the epidemic season was deemed to extend from October 1964 to September 1965.

As in the case of the previous epidemic season, an appropriate onset map was constructed (figure 4.14.) from the evidence presented by the maps of monthly notification rates (figures 4.9. and 4.10.). Subsequent interpretation, again using schematic flow-lines, revealed a more complex pattern than in the previous epidemic, although even so a number of interesting features emerged.

Two principal foci of infection were suggested by the distribution of the onset months. From these points, there appears to have been a widespread spread of the virus. The more important of the two, epidemiologically-speaking, centred upon Sunderland C.B., and incorporating the adjacent urban areas of Seaham, Boldon and Hebburn, and Sunderland Rural District, experienced an epidemic rise during October 1964. In the south-west of Durham, which constituted the second focal area, the local authorities of Crook and Bishop Auckland, together with Darlington R.D., all exhibited a remarkably early onset during October 1964.

In the first of these two areas, the immediate epidemic spread appears to have been considerably localised, as is indicated by the occurrence of relatively late onset months for the adjacent local authorities, extending in an arc from Felling U.D. to Easington R.D. On the other hand, the dissemination of the virus from south-west Durham seems, from an examination of figures 4.9. and 4.10., to have been rapid and relatively uninhibited. Furthermore, it would appear that the early epidemic rise in Bishop Auckland and Crook represented merely a pre-epidemic phase. The true epidemic onset did not occur until much later - viz. March 1965. In this case the disease appears to have doubled back on itself, after the initial period of seeding (Andrews 1951). It is this particular factor which accounts for the inclusion of two separate onset months, for these two local authorities (figure 4.14.).

4.5. The influence of aetiological factors in epidemic spread

The majority of previous work on the generation of measles epidemics has attached particular importance to the accumulation of susceptible material as the initiating factor in epidemic spread. Indeed Wilson (1905:81) goes so far as to discount the influence of

"atmospheric or similarly widespread conditions". However, since susceptible accumulation following an epidemic phase - either by birth and/or immigration - is by no means a constant process, it is perhaps difficult to account for the extreme regularity of measles epidemics purely in these terms. Consequently, it was postulated that there must be an additional factor or factors which would act as a trigger or catalyst in promoting epidemicity. It was the search for such a factor which formed the major part of this study. The results of this investigation are summarised below, under a number of factor headings.

4.5.1. Population size

By correlating the home population of each local authority with the corresponding notification rates, it was hoped to discover whether or not the demographic size of settlements played a part in determining the incidence and distribution of measles.

Although a substantial number of correlations were undertaken, employing the weekly, monthly and annual notification rates for the three epidemic periods, at no time did the coefficients of correlation achieve a sufficient level of statistical significance ($0.05 > P$). It may therefore be concluded with a considerable measure of confidence that settlement size in itself appeared to be exerting little or no influence upon the distribution of measles within the county.

4.5.2. Density

The relevant statistics for three indices of population density were abstracted from the county census returns for each local authority as follows:-

- (a) Physical density, the number of persons per acre.

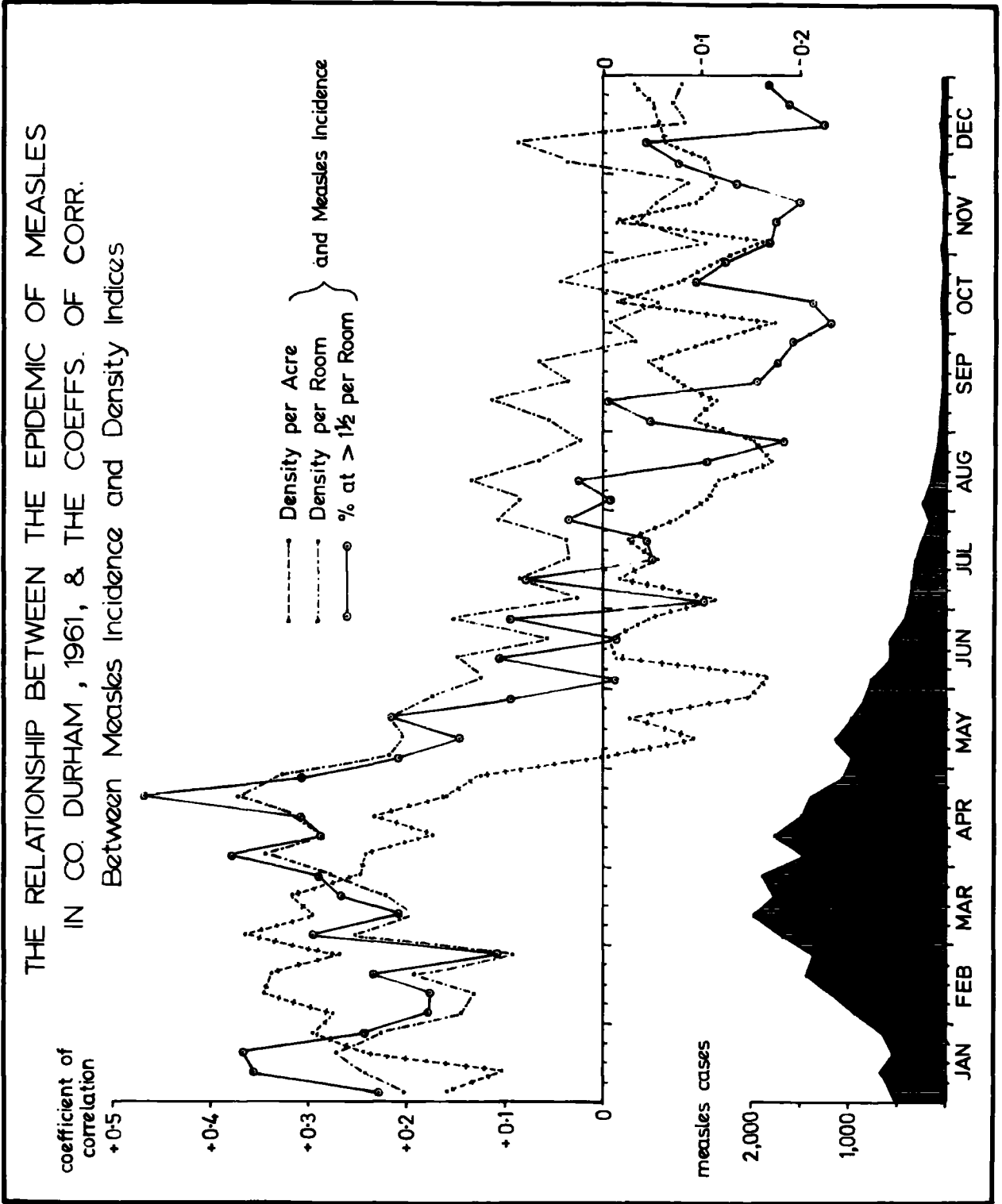


Figure 4.15.

- (b) Social density, the number of persons per room.
- (c) Overcrowding, the percentage of persons living at more than $1\frac{1}{2}$ persons per room.

The necessity of considering three different density factors, springs from the recognition of three distinct levels or processes involved in the actual dissemination of the disease. Firstly, there is the transmission of infection from settlement to settlement; secondly, there is the transfer of the virus between households in a particular settlement or neighbourhood unit (often facilitated by the local school); and thirdly there is the passage of the disease from individual to individual within a single family.

For the epidemic year 1961, the three density indices were correlated with the weekly notification rates for the forty local authority areas in County Durham. This yielded a sequence of 52 coefficients of correlation for each of the density factors. These were then plotted out as a time series; which facilitated a visual correlation with the epidemic regime for the corresponding period (figure 4.15.). It may be seen how closely the coefficients of correlation for the three indices correspond with the various stages of epidemicity.

During the early stages (middle of January) a significant association was seen to exist between the spatial distribution of measles incidence and the percentage of the population living at more than $1\frac{1}{2}$ persons per room. This suggested that in the pre-epidemic stages of the cycle, the virus was gathering momentum in the areas with a high level of overcrowding. In this respect, the whole of Tyneside, Wear-side and the Hartlepool area appear to be particularly favourable locations, with over 10% of the population living at more than $1\frac{1}{2}$ persons per room. Indeed it is perhaps not surprising to discover that three out of the four designated epidemic foci were located in these areas.

From the beginning of February to the end of March 1961 - the period including the peak of the epidemic - it was density per acre which produced the most significant degree of association with the incidence of measles. This trend was indicative of the dissemination of the infection from the major epidemic foci to adjacent urban areas of high density housing. However, it appears that this process of dissemination was concentrated predominantly in the northern part of the County, and especially in south Tyneside. This fact may help to explain why there was no apparent association between the population size of local authorities and measles incidence.

From the end of March to the end of April, overcrowding again asserted itself in the statistical determination of the disease pattern. This suggested that the virus was being disseminated even further afield during this period, especially to those localities exhibiting a high degree of nucleation in association with poor or inadequate housing conditions - e.g. the urban districts of Seaham, Hetton and Consett.

During the period of epidemic wane, from the beginning of May to the end of September, the coefficients of correlation between density per acre and measles incidence were consistently negative in sign, although statistically insignificant. This seemed to suggest that the virus, having run its course in the major urban areas of Durham, was now engaged upon a systematic infiltration of the more dispersed settlements, particularly in the centre and west of the county (cf. figure 4.6.). The validity of this hypothesis was enhanced by the contemporaneous decline in the degree of correlation involving the overcrowding index. This once again was indicative of the migration of the epidemic wave to a more dispersed social environment. However, it should perhaps be borne in mind that as the epidemic wanes the statistical significance of correlations based upon progressively smaller numbers of measles

notifications, invariably declines. Thus it is perhaps unwise to draw more than tentative conclusions from the data during this period.

4.5.3. Meteorological factors

Since all three measles epidemics under consideration had exhibited a markedly seasonal character - with an initial rise during autumn or early winter, and a peak incidence occurring during the first quarter of the following year (figure 4.1.) - it was thought likely that particular meteorological factors might be exerting an aetiological influence, in promoting the onset of epidemic conditions. With this in mind, an initial investigation was made to see whether such a relationship or relationships could be proved at the local level. Accordingly, monthly statistics for nine climatic variables - including the parameters of temperature, rainfall, sunshine, cloud cover, air pollution and wind speed - for the Durham University observatory were correlated with the corresponding monthly notification rates for the years 1961-65 inclusive.

Of the 100 coefficients of correlation which were obtained only 5 proved to be statistically significant ($P < 0.05$), and all of these were associated with the single variable of air pollution. Moreover, even in the case of this factor, the coefficients of correlation obtained were seen to vary quite considerably from year to year, and they only achieved a sufficient degree of statistical significance ($P < 0.05$) in fifty per cent of cases.

4.5.4. Atmospheric pollution

Despite the rather unconvincing results obtained from the initial analysis of the meteorological parameters, the suggested, if intermittent, association between the incidence of measles and air pollution was adopted as a working hypothesis for more detailed investigation.

Measles Incidence For	A/Pollution For	Av. Smoke	Highest Smoke	Av. SO ₂	Highest SO ₂
GATESHEAD C.B.	Gateshead C.B.	+0.09	+0.48	+0.08	-0.06
FELLING U.D.	"	+0.27	+0.59*	+0.30	+0.11
HEBBURN U.D.	"	+0.33	+0.52	+0.70*	+0.35
JARROW M.B.	"	0.64*	+0.78**	+0.81**	+0.62*
BLAYDON U.D.	Blaydon U.D.	-0.13	-0.11	-0.28	-0.20
RYTON U.D.	"	-0.27	-0.36	-0.30	-0.32
STANLEY U.D.	"	+0.40	+0.25	+0.72**	+0.71**
WHICKHAM U.D.	"	-0.53	-0.47	-0.42	-0.42
W. HARTLEPOOL C.B.	W. Hartlepool	+0.20	+0.22	+0.08	+0.12
STOCKTON R.D.	"	-0.40	-0.45	-0.47	-0.60*
HARTLEPOOL M.B.	"	-0.47	-0.45	-0.35	-0.26
S. SHIELDS C.B.	S. Shields C.B.	+0.22	+0.40	+0.88***	+0.66*
BOLDON U.D.	"	+0.22	+0.09	+0.50	+0.22
SUNDERLAND C.B.	"	+0.12	+0.25	+0.67*	+0.39
STOCKTON M.B.	Middlesbrough	-0.63*	-0.53	No results	No results
BILLINGHAM U.D.	"	-0.59*	-0.42	No results	No results
DARLINGTON C.B.	"	-0.09	-0.25	No results	No results

Table 4.2. The Coefficients of Correlation between Measles Incidence and Air Pollution Indices (by month) for Selected Local Authorities in County Durham, 1961.

Significance levels: * 0.05 > p > 0.01

** 0.01 > p > 0.001

*** p < 0.001

Appropriate monthly air pollution statistics were collated for as many other sample points as possible in County Durham (Warren Spring Laboratory) for the three epidemic seasons and for the following four parameters:-

- (a) The mean daily smoke concentration
- (b) The highest daily smoke concentration
- (c) The mean daily concentration of atmospheric Sulphur Dioxide
- (d) The highest daily concentration of atmospheric Sulphur Dioxide

(In each case the concentration is given in microgrammes per cubic metre).

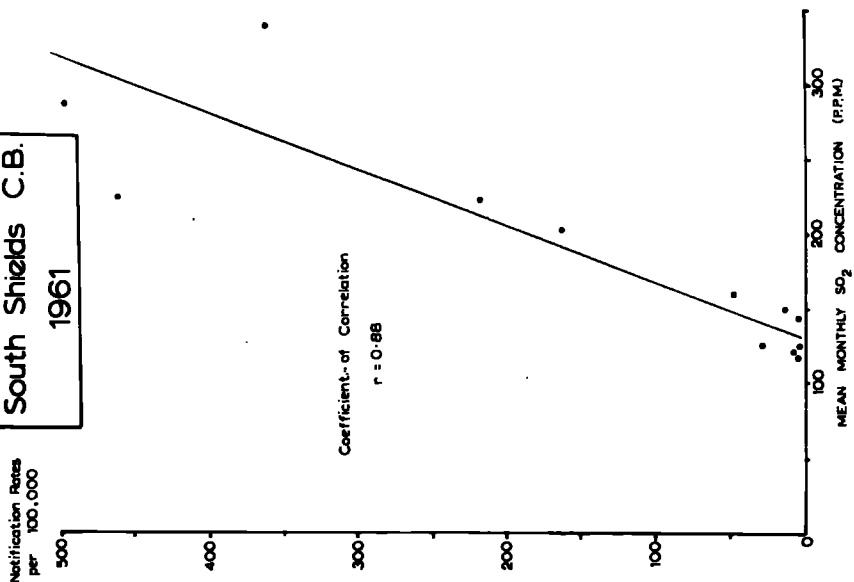
At the beginning of the five year period, there were only four local authorities in the whole of County Durham officially recording atmospheric pollution. As a result, it was deemed necessary, under certain circumstances, to sanction the application of air pollution data for a given site to a number of surrounding local authority areas which did not have recording facilities. For example, the 1961 air pollution statistics for Gateshead were adopted for use in the consideration of Felling, Hebburn and Jarrow, as well as for the county borough itself.

4.5.4.1. The 1961 epidemic

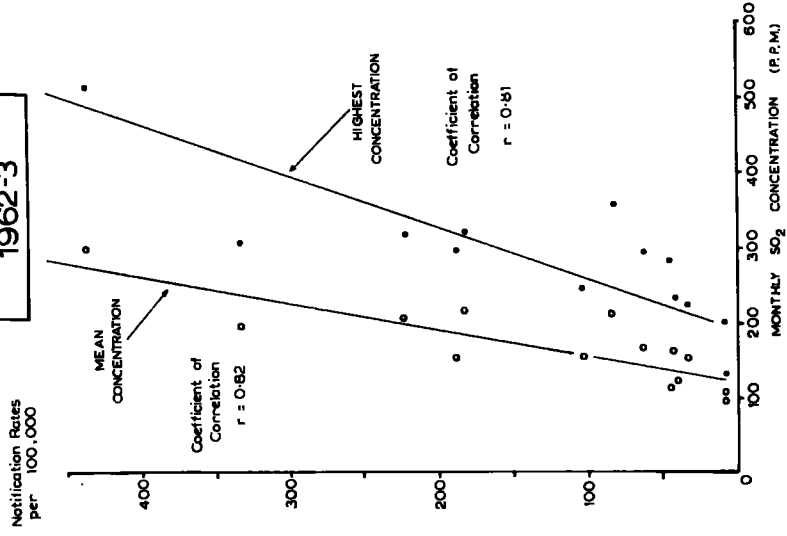
In 1961 (Table 4.2.), it may be seen how the majority of significant correlations were (a) positive in sign and (b) associated with sulphur dioxide levels rather than the amount of smoke in the atmosphere. The only two significant negative correlations were recorded in the cases of Stockton M.B. and Billingham U.D., and utilising the pollution data for Middlesborough. However, as has already been noted (section 4.4.2.1. above) during the 1961 epidemic period, Teesside appears to have been completely anomalous both in terms of its overall incidence of measles and also its peculiar epidemic regime.

Air Pollution and Measles in County Durham

South Shields C.B.
1961



Hebburn U.D.
1962-3



Sunderland C.B.
1964-5

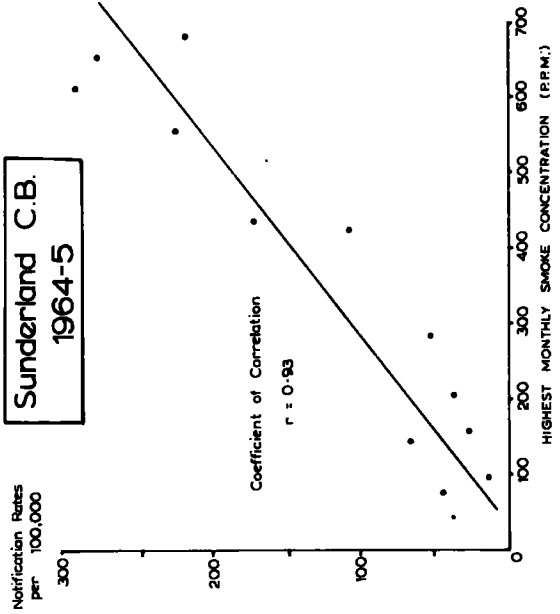


Figure 4.16.

Of the local authorities exhibiting positive correlations between measles incidence and air pollution characteristics, particularly high correlations ($P < 0.01$) were found in the case of two of the epidemic foci defined in terms of epidemic onset. For the urban district of Stanley, the values for both the average and the highest concentration of atmospheric sulphur dioxide (recorded for Blaydon) correlated very significantly ($P < 0.01$) with the corresponding monthly notification rates for measles, although the results for smoke pollution were not quite so encouraging. In the case of South Shields C.B. a similar range of coefficients was noted. The left-hand diagram in figure 4.16. indicates that the correlation involving the mean daily concentration of sulphur dioxide was particularly marked (coefficient of correlation $+0.88$, $P < 0.001$). It is also interesting to note that the adjacent local authority of Jarrow displayed a similar degree of statistical association (utilising the pollution data from Gateshead C.B.). It would appear that Jarrow, by virtue of its proximity to South Shields, displays many of the epidemiological characteristics of the focal areas themselves.

One surprising anomaly in the overall situation is provided by the lack of statistical association between air pollution and the incidence of measles in the Hartlepool area, which was originally defined as one of the epidemic foci. Indeed, the coefficients of correlation were consistently negative in the case of Hartlepool M.B. which would suggest, if anything, an inverse relationship.

4.5.4.2. The 1962-63 epidemic

For the 1962-63 epidemic season, a total of eight local authority areas were investigated, including the proposed epidemic focus of Hebburn U.D.

Local Authority	Air Pollution Site	Av. Smoke	Highest Smoke	Av. SO ₂ Conc.	Highest SO ₂ Conc.
BLAYDON U.D.	Blaydon	-0.44	-0.11	-0.35	-0.05
CONSETT U.D.	Consett	+0.00	+0.05	+0.06	+0.07
SUNDERLAND C.B.	Sunderland	-0.16	-0.03	-0.16	+0.03
GATESHEAD C.B.	Gateshead	+0.08	+0.44	+0.04	+0.23
HEBBURN U.D.	Gateshead	+0.76**	+0.82***	+0.83***	+0.81***
WEST HARTLEPOOL	Hartlepool	-0.37	-0.15	-0.35	-0.10
SOUTH SHIELDS C.B.	South Shields	+0.29	+0.10	+0.17	+0.36
JARROW M.B.	Jarrow	+0.36	+0.29	+0.33	+0.16

Table 4.3. Coefficients of correlation between the monthly notification rates for measles and indices of atmospheric pollution for selected local authority areas in County Durham, October 1962 - September 1963.

Significance levels: * 0.05 > p > 0.01 ** 0.01 > p > 0.001 *** P < 0.001



Table 4.3. reveals that it was once again the focal area which provided the most significant statistical correlations. Three out of the four parameters studied yielded coefficients of correlation which were statistically speaking very highly significant ($P < 0.001$). The regressions involving the sulphur dioxide content of the atmosphere are shown in figure 4.16. It is also interesting to note that, as in the case of the 1961 epidemic, the adjacent local authorities of Jarrow, South Shields and Gateshead all exhibited consistently positive coefficients, whilst more remote areas from the epidemic focus, such as Hartlepool, Sunderland and Blaydon displayed a preponderance of negative coefficients, indicating an inverse relationship.

4.5.4.3. The 1964-65 epidemic

In the last of the three epidemic periods, with an epidemic focus on Wearside and another in south-west Durham, it was once again the focal area which displayed a remarkably high degree of statistical association between air pollution and measles (see table 4.4.). In the case of Sunderland (b) site, the coefficient of correlation between measles and the highest concentration of smoke was 0.93 ($P < 0.001$) which is statistically speaking very highly significant. Indeed, expressed in another way, over 86% of the variation in monthly notification rates for measles could be explained in terms of this single variable. The regression between these two variables is shown in the right-hand diagram of figure 4.16. In addition, since a very similar measure of statistical association was obtained by using air pollution data for three other completely different recording sites within the county borough, the possibility of chance fluctuations may be discounted with an even greater measure of confidence.

In the case of Consett (a) site the statistically significant correlation between the mean daily sulphur dioxide concentration and

Local Authority	Air Pollution Site	Av. Smoke	Highest Smoke	Av. SO ₂ Conc.	Highest SO ₂ Conc.
BILLINGHAM U.D.	a	+0.20	+0.02	+0.05	-0.05
CHESTER-LE-STREET U.D.	a	+0.32	+0.12	-0.05	-0.16
CONSETT U.D.	a	+0.00	-0.11	+0.89***	+0.08
	b	-0.02	-0.06	-0.53	-0.57
	c	-0.00	-0.13	+0.41	-0.12
DARLINGTON C.B.	a	-0.54	-0.41	No data	No data
GATESHEAD C.B.	a	+0.49	+0.12	+0.39	+0.20
	b	+0.32	+0.00	+0.42	+0.38
HARTLEPOOL M.B.	a	+0.52	+0.57	+0.37	+0.48
	b	+0.56	+0.57	+0.39	+0.05
	c	+0.56	+0.54	+0.40	+0.39
JARROW M.B.	a	-0.22	-0.30	-0.33	-0.27
RYTON U.D.	a	+0.06	-0.10	+0.44	+0.33
SEDGEFIELD R.D.	a	+0.68	+0.57	No data	No data
STANLEY U.D.	c	-0.27	-0.04	-0.28	-0.02
SUNDERLAND C.B.	a	+0.77**	+0.85***	+0.84***	+0.86***
	b	+0.86***	+0.93***	+0.87***	+0.90***
	c	+0.78**	+0.89***	+0.84***	+0.87***
	d	+0.83***	+0.94***	+0.82**	+0.89***
WEST HARTLEPOOL C.B.	a	+0.77**	+0.73**	+0.59*	+0.55

Table 4.4. Coefficients of correlation between the monthly notification rates for measles and indices of atmospheric pollution for selected local authorities in County Durham, June 1964 - May 1965.

Significance: * 0.05 > P > 0.01 ** 0.01 > P > 0.001 *** P < 0.001

measles, appears to be a spurious result, since it is completely at variance with the corresponding coefficients of correlation obtained from the other two air pollution sites.

Unfortunately, suitable air pollution data for the south-west area of Durham were not available, and consequently it was not possible to investigate whether this area was behaving in a similar fashion to the other focal area of Wearside in respect of this particular aetiological relationship. On the other hand, in the case of West Hartlepool, although there was no reason to suspect that the area was a primary focus of epidemicity from the cartographic evidence presented in figure 4.14., the consistently positive and significant coefficients of correlation tended to indicate that the area was behaving in a very similar fashion to the main focal area of Wearside. For this reason, it was thought likely that West Hartlepool might have been acting as a secondary and independent reservoir of infection, if only for the local area.

4.6. Discussion

The search for possible aetiological factors concerned in the epidemiology of measles had revealed a considerable measure of statistical association between the onset of epidemic conditions and the annual regime of air pollution, and particularly the sulphur dioxide content of the air. Indeed, it was postulated that it was the actual build up of pollutants in the atmosphere during autumn and early winter which acted as a catalyst in the generation of epidemics, given the availability of a suitable number of susceptibles within the population.

However, once the outbreak of the disease reaches a given threshold value, the influence of such meteorological variables diminishes rapidly, and the process becomes self-sustaining, until the pool of susceptible material has been reduced to some critical level, and the

epidemic wanes. During this secondary phase, a number of social and demographic factors play an increasingly important part. In particular the role of density factors in determining epidemic spread appears to be important.

At first sight, the association between atmospheric pollution and measles might seem to represent merely a statistical anomaly which defies rational explanation. However, upon reflection, two quite feasible explanations emerged and these are discussed below.

Firstly, since air pollution has already been widely recognised as a contributory factor in a large number of respiratory disorders (see for example Daly 1954 and 1959; Douglas and Waller 1966; Fairburn and Reid 1958; and Laidlaw 1960) it is perhaps not unreasonable to suppose that a population which has been physically weakened by prior infection of the respiratory tract, induced in part by atmospheric pollution, will have a much lower resistance to infection by measles. However, since in the majority of respiratory diseases the part played by air pollution, although statistically significant, is nevertheless relatively complicated by the action of a considerable number of other variables, it was thought unlikely that this somewhat indirect relationship could produce such a high degree of statistical association. Thus, although the prior infection of the respiratory tract might be regarded as a contributory factor in the 'conditioning' of the population, it was discounted as constituting the major factor in the initiation of epidemic conditions.

The second explanation rests on the work of Papp (1956). He found by extensive clinical experimentation that the transmission of the measles virus did not appear to take place from one respiratory tract to another, as thought previously. Instead, Papp concluded that the entry of the virus into an individual takes place through the corner of the eye: "Les examens effectués jusqu'ici montrent que le virus de

la rougeole ne penetre pas dans l'organisme - comme on le croyait généralement - par les muqueuses des voies respiratoires supérieures. Son seul accès, son unique porte d'infection, est l'oeil et il passe dans le sang à travers une conjonctive saine". (p.32). Since it is well known that even moderate levels of atmospheric pollution can induce quite a number of deleterious effects in the delicate structure of the eye - such as aqueous discharges and inflammation - it is perhaps not unreasonable to postulate that the onset of increased air pollution conditions would generate an exceptionally fertile soil for this particular mode of transmission. Moreover, the pollution particles themselves would facilitate the actual transfer of infection, by acting as suitable nuclei for the virus during the actual transmission stage, from individual to individual.

4.7. Conclusions

The study has shown that in the case of County Durham, the regular epidemic regime for the county as a whole (figure 4.1.) is in fact composed of a number of independent and localised outbreaks. Thus individual local authorities experienced epidemic conditions at widely differing times during the biennial cycle. Some areas appear to have escaped infection almost entirely during a particular epidemic season - for example the rural district of Stockton during 1961 (table 4.1.) - while others experienced prolonged periods of persistent epidemicity, even during the well-defined inter-epidemic periods - as in the case of Brandon U.D. during the period October to December 1963 (figure 4.8.). Burnett (1962:19) has likened such epidemiological phenomena to the effects of a forest fire, "which does not recur until fresh undergrowth has grown up. Sometimes it misses a patch for years. However, when these patches which have missed the fire for many years are at last reached the overgrown inflammable material blazes fiercely, and many

more trees are liable to be destroyed here than elsewhere".

Despite the inherent complexity of the situation, major foci were defined for each of the three epidemic periods, and the major lines of dissemination mapped. In the main, the primary foci were located in the densely-populated areas of south Tyneside and Wearside, with important secondary foci in the centre and south-west of the county. However, there did not appear to be a single constant epidemic focus, or even a constant endemic area.

It was discovered that, in addition to the susceptibility/immunity factor already defined by Stocks and Karn (1928), population density appeared to be an important 'conditioning factor' in assisting the transmission of the measles virus. In particular, the effects of density per room were found to be extremely significant in the determination of epidemic spread.

An initial investigation of particular meteorological variables revealed that there was little or no relationship between the incidence of measles and these purely climatic variables. However, the related factor of air pollution did suggest itself as a possibility for further investigation. Subsequent analysis revealed that in each of the three epidemic seasons, proposed epidemic foci exhibited a remarkably high degree of statistical association with two or more of the parameters of atmospheric pollution. It was concluded from these observations that, given suitable epidemiological pre-conditions - viz. the accumulation of a sufficient number of susceptibles in the population - then a significant rise in the level of particular pollutants in the atmosphere would provide the necessary trigger or impetus for the initiation of widespread epidemic conditions. Moreover, this conclusion appears to be supported by the clinical experiments of Papp (1956) concerning the mode of transmission of the virus.

It is of course realised that by studying such a relatively limited time period for a single county, the results in themselves cannot be regarded as particularly conclusive or universal. However, the statistical significance of many of the results, especially in the case of air pollution, tends to suggest that there are indeed a number of underlying causal relationships which undoubtedly warrant further study, in a wider spatial and time perspective from the geographical angle, and also from the clinical point of view.

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Chapter 5Tuberculosis in County Durham 1961-655.1. Introduction

"Tuberculosis is an endemic disease always present in our midst, slow and insidious in its progress, protean in its manifestations, selecting its victims with an almost discriminating partiality." (Gloyne 1944:8). Nevertheless, it is an infectious disease passed from individual to individual as a result of sustained periods of contact. (See Appendix B) The stealth and haphazard nature of its advances, in comparison with the relative uniformity of regime displayed by such exanthemata as measles or scarlet fever, originally suggested a completely random process of victim selection, and attributable to such phenomena as "mysterious vapours" or "a veritable blast from the stars". (Greenhow 1857:79) However, as knowledge has advanced, it has come to be realised that, in many ways, the incidence of tuberculosis appears to be more closely responsive to local environmental conditions than many faster moving infectious diseases, such as measles and scarlet fever. The latter invariably generates a substantial momentum, which acts to override the state of concordance with the local conditions. Indeed, until quite recently, incidence rates for tuberculosis were quite extensively used as indicators of the general health of the community, and thereby of associated living conditions.

In one sense, of course, there can only be a single cause of tuberculosis - the tubercle bacillus - which for all intents and purposes may be regarded as a working constant. However the "causes of tuberculosis" which are discussed below are phenomena which, by virtue of facilitating the implantation of the tubercle bacillus within the

body, or generally aiding the progress of the disease once it has become established, qualify for recognition as causal factors. It is the action of these causal factors (which are all integral elements of the environment) which produces the considerable differentiation of incidence and mortality, which occurs even between contiguous areas.

As will become apparent from the following study, it is almost impossible to isolate particular elements from the intricate web of causation, since the majority of the causal factors are themselves intimately related. Consequently, it was deemed to be more appropriate to build up a theoretical model of causation rather than to dissect the system into its individual items, which would merely serve to destroy the identity of the system.

So far, the spatial investigation of tuberculosis has been confined essentially to the consideration of national statistics (McDonald 1952, Merrett 1955, Stocks & Karn 1931); particular sectors of the community (Collis 1925, D'Arcy Hart et alia, 1942); or the investigation of relatively large urban complexes such as Birmingham, Glasgow and Tyneside (Bradbury 1933, Stein 1950 & 1952, McMillan 1957, Springett et alia 1958, Webb & Stewart 1951). A notable exception to this was the article written by Jessop in 1955, and concerned with reservoirs of pulmonary tuberculosis in Warwickshire. However, this particular study was undertaken at a rather superficial level, being concerned principally with statistical method rather than causal inquiry.

The aim of the present study is to attempt an investigation at an intermediate scale, thereby offsetting the effects of continual generalisation associated with the analysis of national statistics, whilst still retaining the advantages of group study. As Stein and Sklaroff comment, "The laboratory of social medicine is the local community, and its interest is focussed on the social group rather than on individuals." (1952:118) In this context, County Durham, considered

at the local authority level, presents itself as a particularly interesting area, since it displays a remarkable variety of both physical and social environments. Moreover, the occurrence within the county boundary of distinct areas of particularly high incidence of tuberculosis, not only augments the statistical significance of the results, but it also considerably enhances the 'raison d'être' of the study. Nevertheless it must be remembered that by undertaking such a study as this, it remains extremely unlikely that new and important discoveries will be made in relation to the causation of tuberculosis. "But the careful and intensive study of tuberculosis in a limited area confirms and puts on a solid statistical basis opinions formerly held as a result of general observation." (Bradbury 1933:ix)

5.1.1. Historical review of tuberculosis

Tuberculosis has been described by Dubos and Dubos as a disease of "incomplete civilisation". (1953:219) Indeed, it is remarkable how during the last century the peak incidence of tuberculosis coincided with the periods of most rapid change, for both individual communities and nations alike. At times during the nineteenth century, the 'Great white plague' seemed to threaten the very survival of the European race. Its effects upon the community were devastating: in some areas accounting for twice the mortality of any other single cause of death. However, by virtue of its ubiquity within the community, and its seemingly random selection of victims, it came to be regarded as an inevitable consequence of life itself. As such it was in no way comparable to the intermittent and highly localised epidemics of such diseases as cholera and typhus fever.

Nevertheless, despite the fact that the nineteenth century ravages of tuberculosis were probably amongst the most spectacular that have occurred, and as such are well documented, this does not mean to say

that the effects of the disease were minimal during earlier periods of history. On the contrary, although the word 'tuberculosis' only appeared in print for the first time in 1840, the disease itself is referred to in many ancient writings in both Europe and Asia. In particular, the description of the disease, contained within the Hippocratic collection of medical essays, is extremely valuable.

However, despite the continuing presence of the disease within the community during the eighteenth and nineteenth centuries, there appeared to be evidence of a certain reluctance on the part of the authorities to take effective measures to combat the ravages of the disease, which was such a drain upon the resources of the community. "Consumptive patients continued to live a life of normal activity almost to the end, not only spoiling any chances of arresting their own disease, but seeding the germs of it all around them." (Dubos & Dubos, 1953:205) In this connection, a Royal edict issued at Naples in 1782, and ordering the isolation of consumptives, and the cleansing of their dwellings, is a notable exception.

In 1865, Villemin, experimenting with rabbits, discovered that the inoculation of tuberculous material derived from human beings tended to produce lesions characteristic of tuberculosis in the rabbits. His theory of infection was revolutionary, and quite contrary to the innumerable theories of causation thus far propounded. The latter included the immoderate love of food, the excessive use of tobacco, and the passion for dancing. (Dubos and Dubos 1953:197) Villemin's findings undoubtedly inspired the work of Koch, who in 1882 isolated the tubercle bacillus, thereby confirming the theory of the infectivity of tuberculosis.

This latter discovery enabled man to mount a direct attack upon the basic causative agent, which was the bacillus. This fact, together with the continuing rise in the standard of living, facilitated in part

by the Public Health Act of 1875, sufficed to effect a marked decline in the levels of tuberculosis in Britain, and in particular in England and Wales.

This encouraging trend was subsequently reinforced by the building of sanatoria for the tuberculous, to facilitate both isolation and cure. Chest clinics were set up in all parts of the country, and extensive surveys were undertaken to ascertain the prevalence of the disease in particular areas. In addition, as a result of the Notification of Infectious Diseases Act, 1888, each local authority was required to notify each new case of tuberculosis that occurred within its boundaries, and also to keep a permanent register of all tuberculous persons residing in the area. More recently, mass x-ray techniques and improved methods of clinical diagnosis have further enhanced the rate of decline in the mortality figures for the disease, although promoting temporary rises in the notification rates. The consequence of all these measures and improvements has been the twenty-four fold decrease in the mortality index for England and Wales between 1851 and 1954 (see the Registrar General's Statistical Review part 1, 1954, table 6).

Nevertheless, despite this encouraging improvement in the overall mortality figures for tuberculosis, particular areas remain as persistent reservoirs of infection. As has been stated above, County Durham, and in particular Tyneside, are remarkable for their continuing high level of both mortality and morbidity (Murray 1962:138).

5.2. Data - Sources and Limitations

Gloyne recognised six principal methods of estimating the general prevalence of tuberculosis in a community - viz. a) tuberculin surveys, which indicate the percentage of the population that has already been infected by the bacillus, although not necessarily displaying overt

clinical manifestations of the disease; b) compulsory notification of active cases of tuberculosis; c) mass radiography; d) mortality statistics; e) records of post mortem examinations, and f) an overall appraisal of some or all of the above in a comprehensive tuberculosis survey. (Gloyne 1944:67)

In general, however, and especially for the purposes of medico-geographical investigation, methods (b) and (d) are undoubtedly of the most value. In England and Wales, both these methods are employed and regulated by a central authority - the General Register Office - and as such the particular statistics are both continuously and universally collated for appropriate areal units.

In the case of notification, each new case is recorded in a special tuberculosis register (e.g. at Durham Rural District); the general infectious disease register (e.g. at Felling Urban District); or on individual index cards (e.g. at Hebburn Urban District). In each case details of the name, sex, age and address of the patient are recorded, together with the name of the notifying doctor. The occupation of the patient is not always recorded, although in most local authorities it is specified where possible.

As a result of the variability in the nature of tuberculosis (see Appendix B), the process fails either to measure the total prevalence of the disease within the community, or to record the period of primary infection in the majority of individuals. Thus "each set of records describes not illness as it occurs, but illness by the definition of what is conspicuous and is brought to the notice of the particular agency." (Stein and Sklaroff 1952:130) In this connection, it has been noted by Dubos and Dubos (1953:223) that over one third of the individuals dying of tuberculosis in particular American cities during the late 1940's and early 1950's were never recorded as being tuberculous at any time during life. This surprising revelation arises

in part from the fact that an individual can in most cases continue to pursue an essentially normal regime of life, until the disease has reached a relatively advanced stage, at which time additional complications rapidly reduce the individual to a terminal state. On the other hand, there is the factor of social stigma associated with tuberculosis which renders particular individuals or families extremely reluctant to declare a suspected case of the disease. Even today, the fear of losing a job, or prospective marriage partner, or the threat of eviction from rented premises, is sufficiently strong to prejudice the chances of notification in a number of cases. Nevertheless, one may assume, for the purposes of this study, that the overall effects of these two processes are essentially uniform over a relatively restricted area, such as County Durham; and thus they will vary in direct proportion to the observed notification rates. The latter may therefore be regarded as tolerably reliable if used merely as comparative indices.

In contrast, death is a finite condition, capable of precise location in time, and as such is not nearly so susceptible to personal prejudice as notification. Nevertheless, at the present time, an ever-decreasing proportion of tuberculosis cases reach a terminal state, and thus in a restricted area of study such as County Durham, the relatively small number of recorded deaths from tuberculosis severely detracts from the statistical significance of subsequent analysis.

With the increasing concentration of tuberculosis mortality in the later stages of adult life, especially in the case of males, the diagnosis of the exact cause of death becomes increasingly more difficult. Thus tuberculosis may be selected from a host of other contributory causes, which, for the purposes of subsequent classification and analysis, are ignored. Moreover, considering the variety of manifestations of tuberculosis which occur, it is not surprising to discover that

the symptoms of other totally unrelated diseases are occasionally classified as tuberculous. This again introduces another minor source of error into the investigation at a comparatively early stage.

Although for the purposes of this present study notification statistics were collated from weekly returns for each local authority in County Durham ("The Registrar General's Weekly Return for England and Wales: Births and Deaths, Infectious Diseases, Weather" H.M.S.O.), most, if not all, of the subsequent analysis was undertaken on an annual or quinquennial basis. This was due to the relatively small numbers of notifications involved, particularly in the case of the smaller local authorities. In fact, even the largest authority - the County Borough of Sunderland - with a population of over 189,000, averaged less than three cases of phthisis per week between 1961-5. By considering longer time periods, chance fluctuations in incidence are minimised, and the effects of intermittent visits by mass radiography units averaged out. The resultant mean notification rates could thus be considered much more reliable, which inevitably increased the statistical significance of the subsequent analysis. On the other hand, by not exceeding a quinquennial time period, longer term fluctuations, reflecting significant changes in the relationships between particular causal factors, were not obscured to any great extent.

In a study of tuberculosis in Glasgow, Lilli Stein recognised the need for more detailed study in a spatial context. "The smaller and more homogeneous the areas considered, the more genuinely the social and economic indices represent characteristics of real meaning in the locality." (Stein 1952:6) This latter observation is undoubtedly valid, but only so long as areal sub-division is consistent with the statistical significance of the basic data. Thus in the case of County Durham, bearing in mind the relatively small number of notifications, the optimum areal unit for the county as a whole was deemed to be the local

authority. Further subdivision would have merely served to enhance the role of chance fluctuations, thereby obscuring the influence of significant relationships.

Nevertheless, it must be borne in mind that even when the local authority is adopted as the unit of study the substantial variation in both the composition and size of particular authorities has a significant effect. In the first place, the smallest units, by virtue of their size, detract from the overall statistical significance of results and conclusions. Secondly, the larger authorities often contain quite distinctive areas displaying certain 'extremes' of environmental conditions (e.g. housing types, etc.) which may be of particular relevance in the causation of tuberculosis. However, by constituting merely a small part of a much larger urban complex, the identity and effects of these areas become inevitably submerged beneath the shroud of the statistical mean. Consequently, it is important to remember that the 'apparent' homogeneity of an area, as portrayed by a number of statistical measures, quite often represents a substantial diversity in reality.

In the case of tuberculosis, many of the factors which have been invoked to explain causation are such that they defy both rigid definition and direct measurement in quantitative terms. The research worker is thus forced to rely on rather indirect means of measurement, often involving a substantial amount of subjective appraisal. For example, Bradbury, in attempting a definition of an 'insanitary dwelling' as a causal factor in tuberculosis, included no less than six criteria, any one of which if present would cause a dwelling to be classified as insanitary. One of these, "The general arrangement of the dwelling and those adjoining it, was a particularly nebulous statement, capable of a variety of interpretations." (Bradbury 1933:42)

Even those factors which are derived directly from official sources display certain inherent limitations, which must be fully appreciated before they are applied in the investigation of causation. For example, in the case of density per room, both the area and volume of individual rooms may vary quite considerably from street to street, and from one local authority to another. Moreover, since the age distribution of individual households is quite obviously not constant, a particular flat which may be deemed adequate accommodation for a married couple and three young children would prove quite inadequate for five adults. It is for such reasons of comparability that arbitrary threshold values, like overcrowding, and indeed many other statistical variables, must be applied with due caution.

5.3. The national situation

The work of Stocks and Karn (1931) tended to suggest that in the period 1921-6, County Durham was experiencing only a slightly higher mortality rate from tuberculosis than the average for England and Wales. (In this particular study, no differentiation was made between respiratory and other forms of tuberculosis.) However, when this situation was further analysed in respect to age and sex, it was demonstrated that considerable differentials did in fact exist. Thus whereas the comparative mortality index for females between the ages of 25 and 44 was situated in the class interval 120-130, the corresponding figure for males in the same age group was only 90-100 - that is below the national average. Unfortunately, this particular study was undertaken only at the county level, and as a result the true significance of particular disease foci within County Durham itself could not be fully appreciated. In this connection, the contemporaneous observation made by Bradbury (1933) that "Jarrow is one of the worst places in England as regards the prevalence of tuberculosis"

would hardly have been suggested by the work of Stocks and Karn (1931).

Subsequently, Murray (1962) took the process of spatial division a stage further by distinguishing individual county boroughs from their respective administrative counties. Nevertheless, in his study of mortality from tuberculosis of the respiratory system, Murray confined himself to a consideration of standardised mortality ratios for males only during the period 1950-53. In this case, the county boroughs of Sunderland, Gateshead, South Shields and West Hartlepool were easily distinguishable as areas of particularly high mortality, with ratios in excess of 1.30 (England and Wales = 1.00). In comparison, the remainder of the administrative county appeared to be close to the national average, with a ratio between 0.90 and 1.09. Even so, it is interesting to note that Durham was only rivalled by seven other English administrative counties in the matter of male mortality from respiratory tuberculosis. Indeed, only London and Cumberland appeared to experience substantially higher comparative mortality ratios than County Durham; whilst Cornwall, Kent, Northumberland and Staffordshire had roughly comparable ratios (viz. 0.90 - 1.09). (Murray 1962, fig. 5.)

Howe (1963) added further sophistication to the work of Murray, firstly by considering both males and females in separate categories which were then mapped, and secondly by allowing for a further areal subdivision of the administrative counties into urban and rural categories.

In the case of males, the standardised mortality ratio for Durham as a whole was substantially higher than the national average, although there were still considerable differences between particular categories of local authorities. Thus the County Boroughs of Gateshead and South Shields had S.M.R.'s in excess of 180 (or 80% above the national average) whilst Sunderland and West Hartlepool C.B.'s were shown to have S.M.R.'s

in the range 140-159. Rather surprisingly, the mortality ratio for the ten rural districts in County Durham (viz. 120-139) was higher than the corresponding figure for the twenty-five urban districts (100-119).

In the case of female mortality, the small numbers of deaths involved must clearly have detracted from the overall significance of the mapped data presented by Howe. Nevertheless, Durham was once again clearly distinguishable as an area of generally high mortality. Gateshead and South Shields in particular stood out as especially unfavourable areas, with S.M.R.'s in excess of 180. In comparison, the combined ratio for the urban districts (120-139) was substantially lower, although still slightly in excess of the ratio for the ten rural districts which lay somewhere between 100 and 119.

From the above evidence, Howe concluded that "If the county boroughs are excluded, only Cornwall and Durham of the 42 administrative counties in England have mortality ratios appreciably above the national average." (Howe 1963:56)

Figure 5.1. shows the geographical distribution of notification rates for the constituent counties of England and Wales between 1961 and 1965, as well as providing some idea of the overall trend in notification rates during the same period.⁽¹⁾

As the map of mean annual incidence demonstrates, there were three distinct areas of particularly high notification rates (over 40 cases per 100,000 persons) namely the north-east of England, the London area, and the northern counties of Wales. In particular, County Durham with an overall notification rate of 44 per 100,000 ranked fifth among the 60 counties after Merionethshire, London, Caernarvonshire and

(1) The data for figure 5.1.were obtained from the Annual Report of the Registrar General, Statistical tables. Part 1. Medical (for the years 1961-1965 inclusive). Table 31.

RESPIRATORY TUBERCULOSIS IN ENGLAND AND WALES

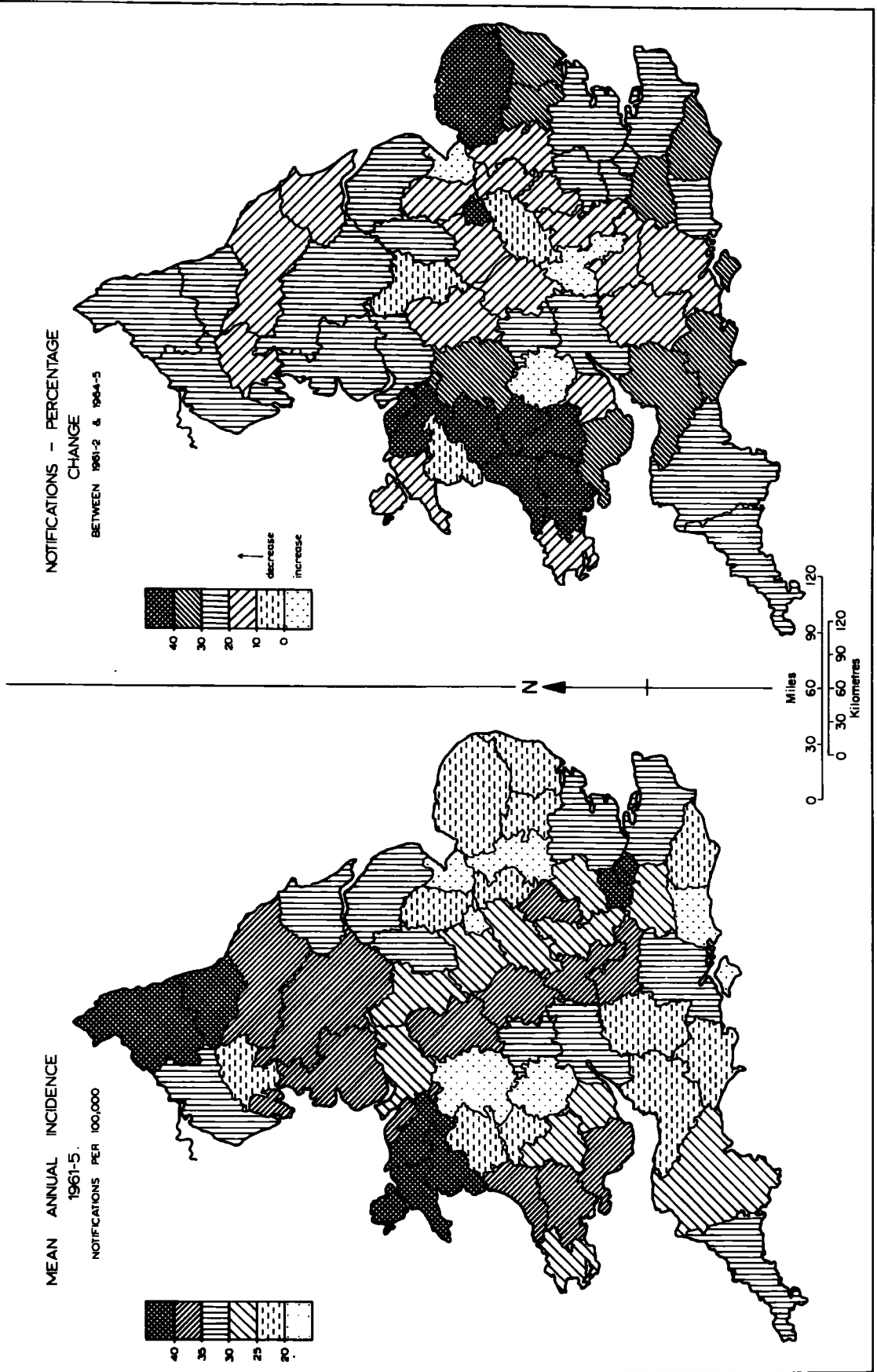


Figure 5.1.

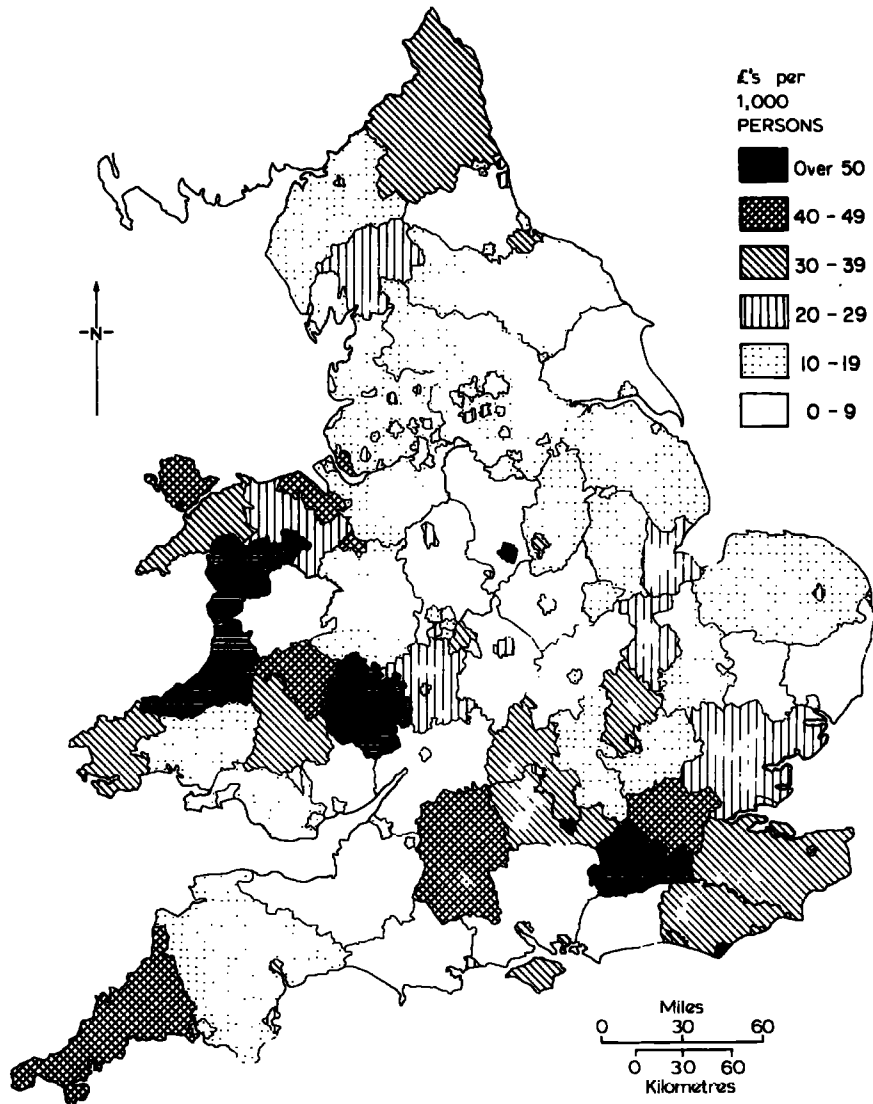
Northumberland, which respectively showed rates of 59, 55, 48 and 45. This compared with a mean value of only 31 per 100,000 for England and Wales as a whole.

The right-hand map of figure 5.1. indicates the percentage change in the number of notifications recorded between 1961-2 and 1964-5. It is interesting to note that most, if not all, of the counties experiencing the greatest percentage decline in notifications were predominantly rural in character - i.e. Norfolk and Suffolk, the majority of the Welsh counties, Somerset, Dorset, Surrey and East Sussex. Moreover, in the case of the English counties cited above, this phenomenon was all the more remarkable, since the overall incidence rates were in the main already significantly below the national average.

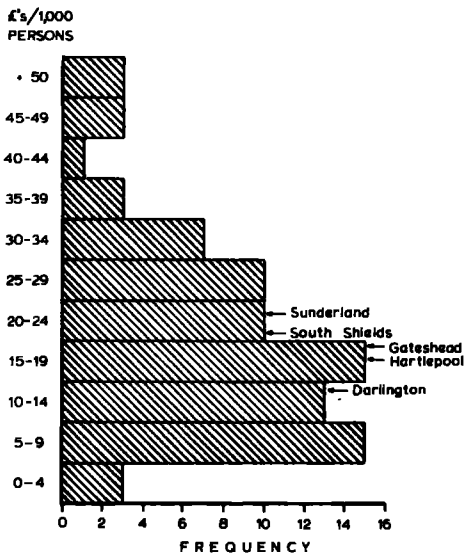
In contrast, the majority of the industrial counties of the country displayed only moderate to low percentage decreases in notifications during the period. This included County Durham with a percentage decrease of only 29. In only three cases - Oxfordshire, the parts of Holland in Lincolnshire, and Herefordshire - was an actual increase in the number of notifications recorded.

It would appear from the above evidence that, at the national level at least, the greatest advances in the control and prevention of respiratory tuberculosis were being achieved in those areas where the disease already displayed a relatively low level of prevalence. In contrast, the eradication of the disease from those areas exhibiting the highest rates of incidence (except in the case of parts of North Wales) was apparently proving considerably more difficult to promote, despite the fact that in all but three cases at least some improvement had been achieved. This process was thereby leading to a situation in which the differential between areas in respect of overall notification rates was becoming steadily more pronounced, and the relative

NET EXPENDITURE ON THE PREVENTION OF
TUBERCULOSIS IN ENGLAND AND WALES
1967-68



COUNTY BOROUGHS



ADMIN. COUNTIES

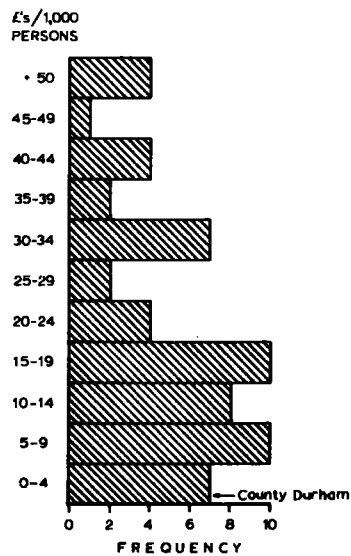


Figure 5.2.

significance of individual disease foci enhanced. In this connection, it is perhaps worthwhile to note the similarity between these observations at the national level and the findings at the county level which are presented in section 5.4.1.2. below.

Having considered briefly the overall distribution of respiratory tuberculosis at the national level, and having defined the more significant foci of the disease, it is perhaps illuminating to consider for a moment the steps which are being taken to combat the disease within the country as a whole. Figure 5.2. was prepared in order to demonstrate the considerable variation in the net expenditure per 1,000 persons on the prevention and cure of tuberculosis, between individual administrative counties and county boroughs, for the period 1967-68. (1)

As may be seen, two of the three areas of particularly high incidence which were identified in figure 5.1., namely London and North Wales, exhibited a correspondingly high level of net expenditure (over £30 per 1,000 persons). In addition, certain other administrative areas which had been shown to have quite low notification rates from respiratory tuberculosis appeared nevertheless to support a surprisingly high level of expenditure on the prevention of the disease. For example, Wiltshire, with a mean annual notification rate of only 24 per 100,000 between 1961-5, spent rather more than £45 per 1,000 of its population in the prevention and cure of Tuberculosis.

In sharp contrast, the situation in County Durham is somewhat disappointing. After Somerset, County Durham emerged as the county with the next lowest net expenditure of all the 60 administrative counties in England and Wales - viz. 4/- per 1,000 persons. Moreover, bearing

(1) The data for Figure 5.2. were derived from the "Local health services statistics, 1967-8", prepared by the Institute of Municipal Treasurers and Accountants and the Society of County Treasurers (1969). Although the statistics do not relate specifically to the period under investigation in this study, the resultant pattern of expenditure may nevertheless be deemed representative, at least in relative terms.

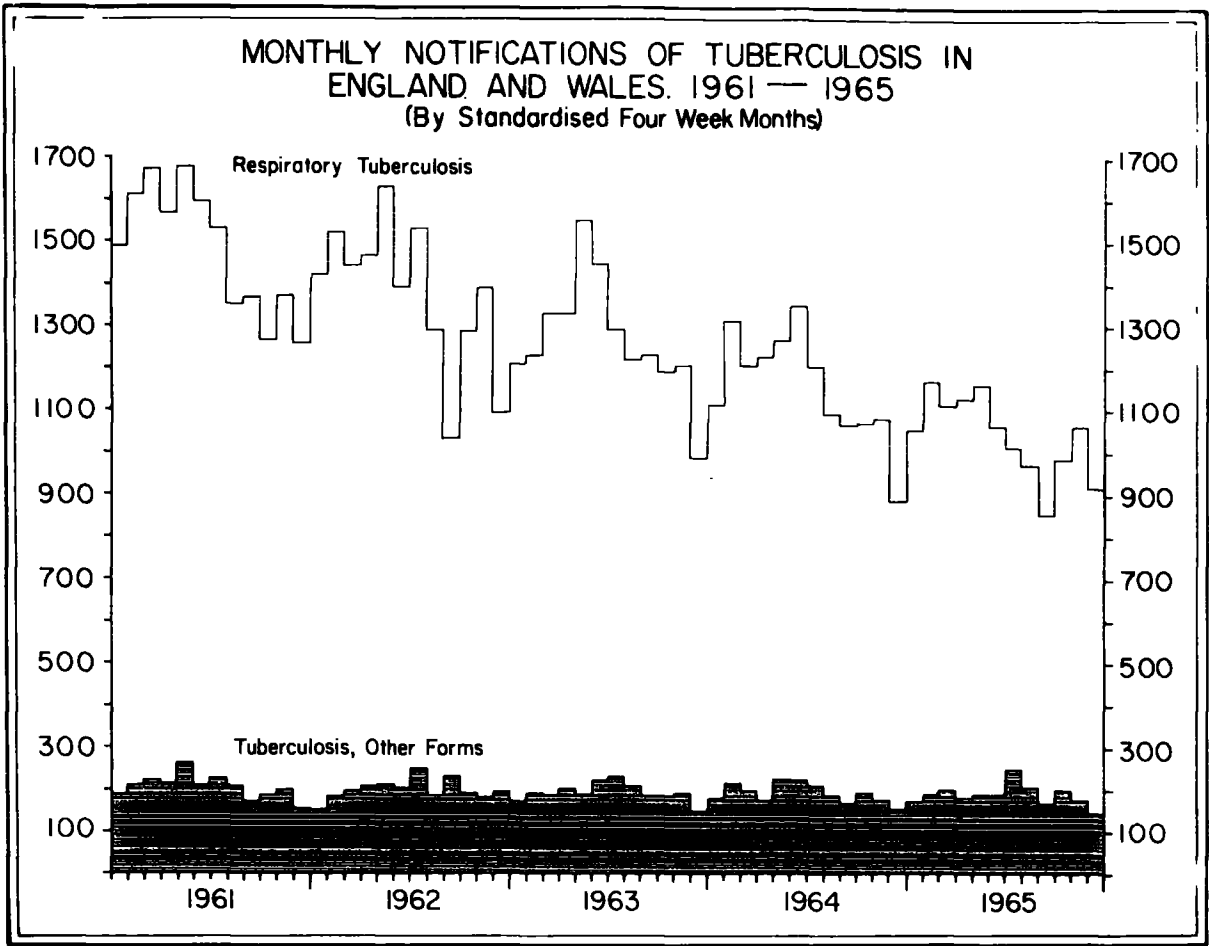


Figure 5.3.

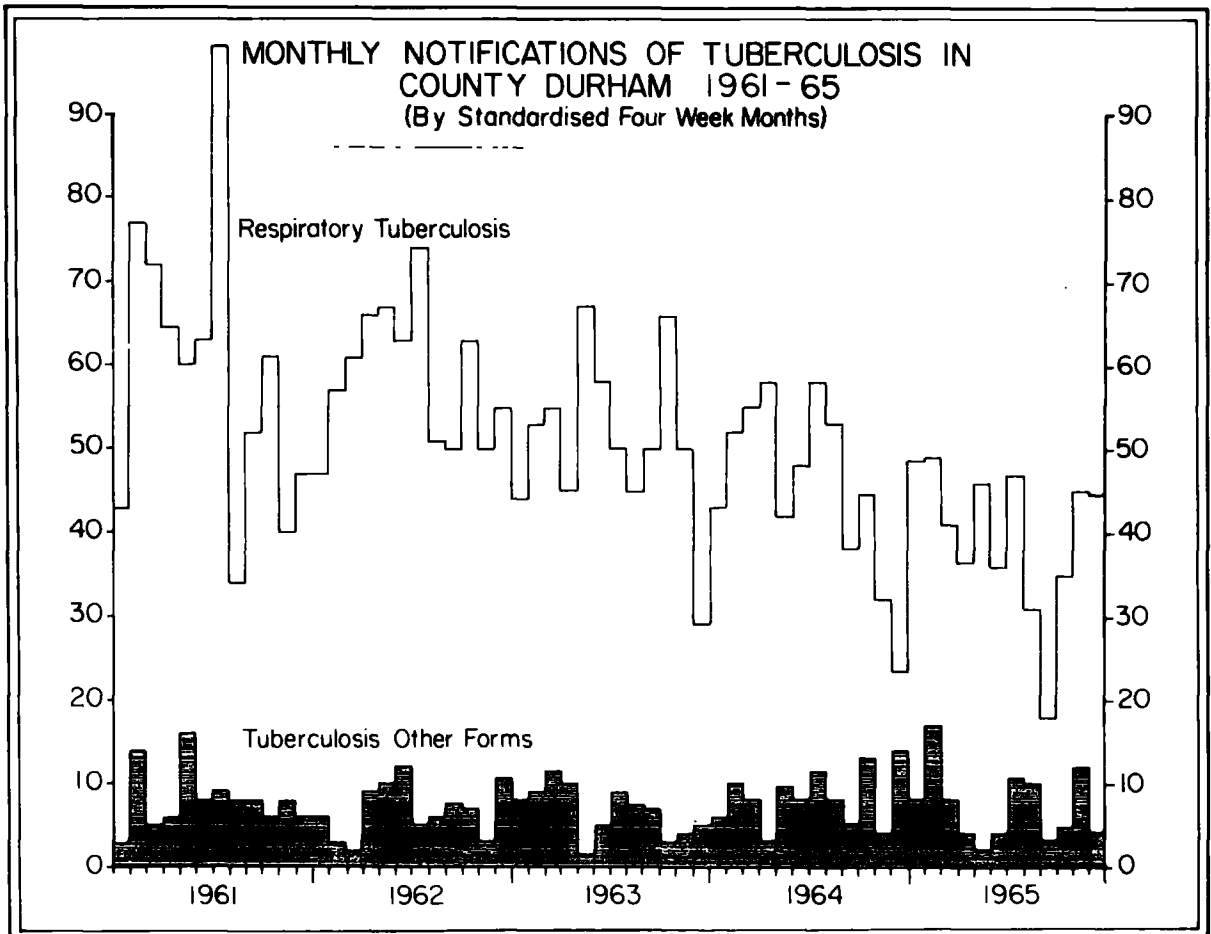


Figure 5.4.

in mind the considerable and persistent reservoir of infection within the major urban areas of the county (see figure 5.6. and table 5.3.) the situation in respect of the county boroughs within County Durham is only slightly more encouraging. As may be seen from the histogram at the base of figure 5.2., each of the five county boroughs concerned spent less than £25 per 1,000 persons; that is to say less than the average net expenditure for all the 124 county and London boroughs in England and Wales.

5.4. Respiratory tuberculosis in County Durham

5.4.1. Temporal aspects

5.4.1.1. Mortality - Relevant statistics collated for the period 1963-7, in connection with section III of this study, did not suggest any significant trend in tuberculosis mortality, at least in the short term. In the five years period, a total of 514 deaths from respiratory tuberculosis were recorded in County Durham; 408 males and 106 females. The annual breakdown of these figures is given in table 5.1.

5.4.1.2. Morbidity - As may be seen from figure 5.4. and table 5.2., the annual numbers of notifications of respiratory tuberculosis for County Durham maintained a steady rate of decline during the period 1961-5. The overall decrease was in the order of 30%. However, considered on a monthly basis⁽¹⁾ (fig. 5.4.) the decline itself appeared to be somewhat more complicated. This situation not only reflects the vagaries of chance fluctuations in notifications, but it is also a rough indicator of the relative activity of, and the response to, the mobile mass x-ray units. Thus it is not surprising to note

(1) In order to facilitate immediate comparison between individual months, the data for figs. 5.3. and 5.4., which were derived from the Registrar General's Weekly Return of Births, Deaths, Infectious Diseases and Weather, were standardised to a four week month, as in the case of the measles data (see Chapter 4 supra).

		1963	1964	1965	1966	1967	Total
MALES	County Bor.	31	28	38	29	26	152
	Urban Dist.	28	30	40	40	27	165
	Rural Dist.	21	19	16	22	13	91
	Total	80	77	94	91	66	408
FEMALES	County Bor.	12	4	7	8	11	42
	Urban Dist.	8	7	8	12	4	39
	Rural Dist.	3	4	4	5	9	25
	Total	23	15	19	25	24	106
MALES & FEMALES	TOTAL	103	92	113	116	90	514

Table 5.1. Deaths from respiratory tuberculosis recorded in County Durham, 1963-7.

	1961		1962		1963		1964		1965	
	Notis.	C.R.	Notis.	C.R.	Notis.	C.R.	Notis.	C.R.	Notis.	C.R.
County Boroughs	340	60	237	43	339	60	278	50	277	49
Urban Districts	286	45	314	50	261	42	247	39	199	32
Rural Districts	116	40	114	39	65	22	70	24	59	20
Total	742	50	665	45	665	45	595	40	535	36

Table 5.2. Annual Notifications and case rates per 100,000 for Respiratory Tuberculosis in Co. Durham, by major Local Authority categories.

that the peaks of notification occur most frequently during the summer months (particularly May and July) whilst the troughs tend to coincide with the periods of autumn and winter. This tends to concur very favourably with the situation obtaining at the national level during the same period (figure 5.3.).

When the situation for County Durham is analysed more closely (table 5.3.), it may be seen that there are significant differentials within the County in respect of the percentage decrease in notifications during the five year period. Thus whereas the ten rural districts in the County recorded a decrease of no less than 4.6% between the two 2-year periods 1961-2 and 1964-5, the corresponding figure for the five county boroughs was only 3.6%. The urban districts, on the other hand, fell into an intermediate position with a 25.7% drop in the number of notifications.

As a statistical check of the above results, the percentage decreases were subjected to a chi-square test (table 5.3.). In the case of both the ten rural districts and the 25 urban districts, the percentage decreases obtained were found to be highly significant ($p < 0.001$). That is to say the percentage decrease in both these cases was not likely to have occurred due to accidents and errors of sampling. On the other hand, the small drop in the number of notifications in the case of the five County Boroughs (3.6%) was not found to be statistically significant.

The general conclusion to be drawn from this situation is that the rural districts of County Durham are experiencing a far more rapid and significant decrease in tuberculosis notifications than their urban counterparts, and in particular the County Boroughs. Moreover, since the rural districts started the five year period with a significant advantage over the other two categories of local authorities in respect

	Cases 1961-2	Cases 1964-5	Per cent decrease	χ^2	Probability
County Boroughs	577	555	3.6	0.8	Not significant
Urban Districts	600	446	25.7	39.8	$P < 0.001, df=1$
Rural Districts	230	129	45.9	44.3	$P < 0.001, df=1$
County Total	1407	1130	29.7	48.0	$P < 0.001, df=1$

Table 5.3. A statistical analysis of the decline in the notifications of respiratory tuberculosis between 1961-2 and 1964-5, in County Durham by local authority category.

	Annual Notification Rates per 100,000	
	1961 - 2	1964 - 5
County Boroughs	51	49
Urban Districts	46	34
Rural Districts	38	22
County Total	46	37

Table 5.4. Mean annual notification rates per 100,000 persons for respiratory tuberculosis in County Durham 1961-2 and 1964-5.

Percentage Change in Notifications of Respiratory Tuberculosis in Co. Durham between 1961-2 & 1964-5

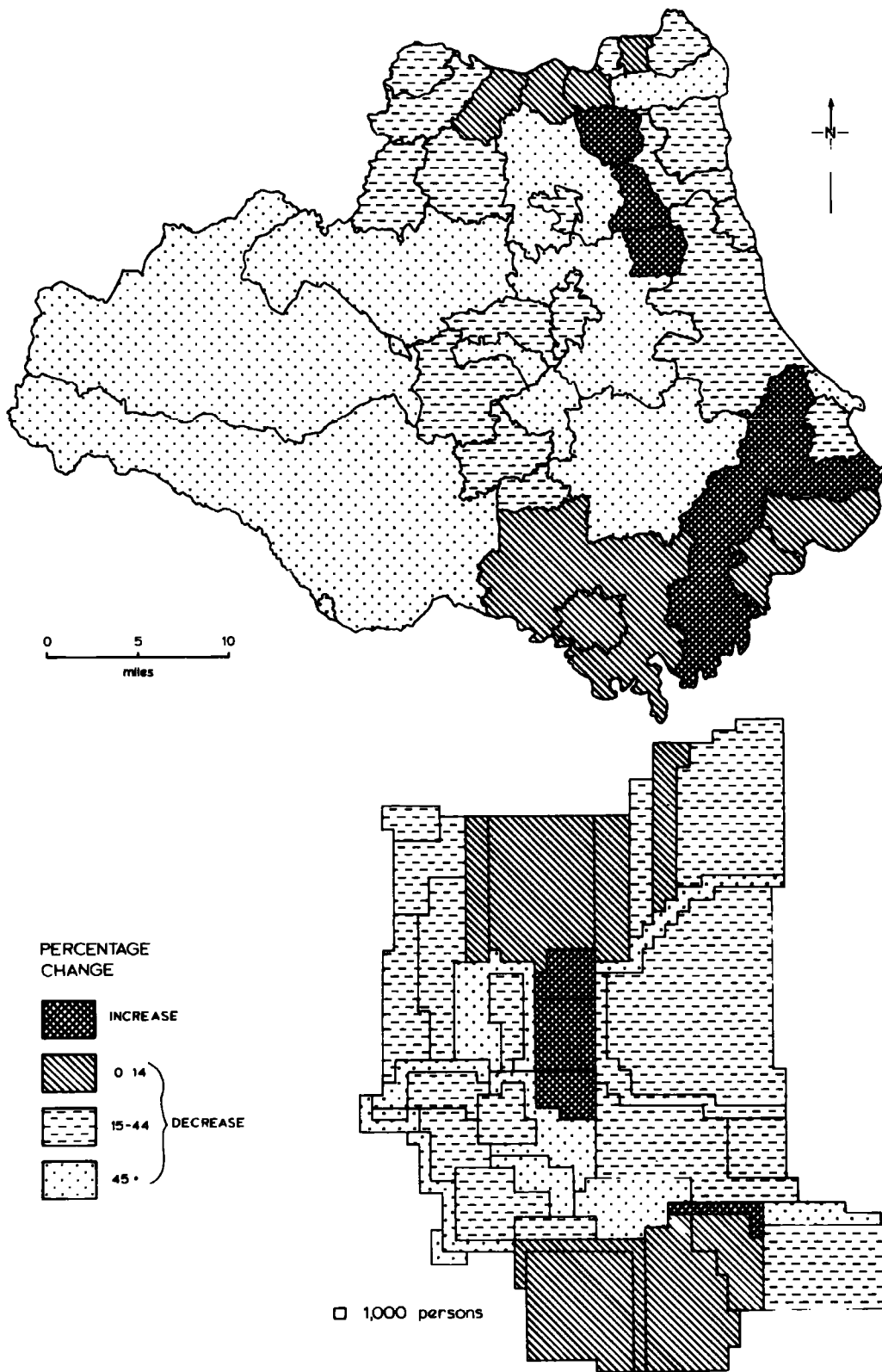


Figure 5.5.

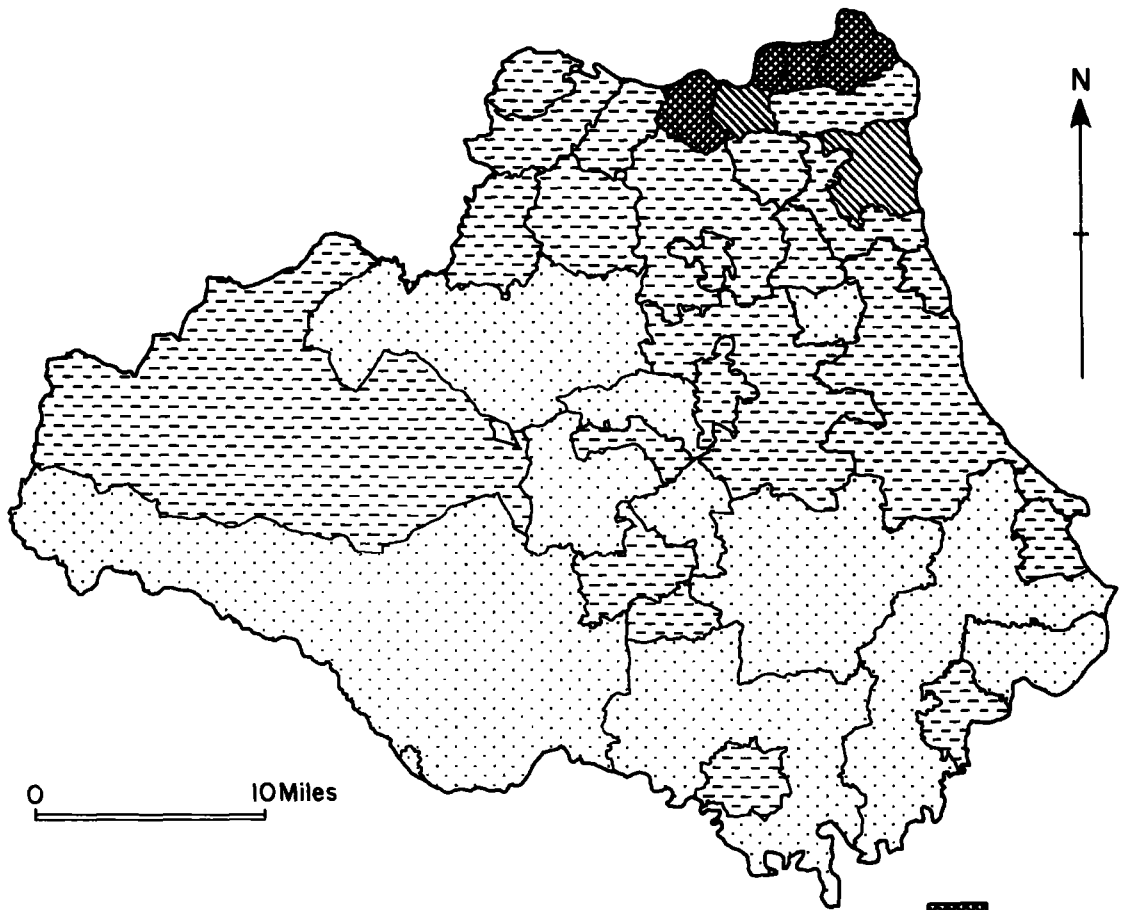
of notification rates (see table 5.4.), this process inevitably led to an even greater disparity between the three categories by the end of the period. Thus, whereas in the years 1961-2 the mean annual notification rate for respiratory tuberculosis in the rural districts was approximately three-quarters the rate recorded for the county boroughs, during the years 1964-5 this fraction had been reduced to well under one-half.

These findings for County Durham contrast sharply with the general postwar observation that "the disease is decreasing faster in larger cities than in rural districts. Once the breeder of tuberculosis, the city may well turn out to be the final cleanser of it." (Dubos and Dubos 1953:224).

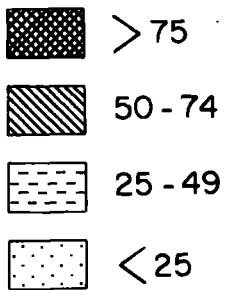
Notwithstanding these quite marked differentials between the three categories of local authorities in respect of the decline of notification rates, other quite substantial local variations were seen to exist. Figure 5.5. demonstrates the relatively small percentage decreases recorded in four of the six local authorities of South Tyneside, and also in the Teesside and Darlington areas to the south. In the contiguous urban districts of Washington, Houghton-le-Spring and Hetton-le-Hole a slight increase in the number of notifications was registered, although this trend cannot be regarded as particularly significant from a statistical point of view.

In contrast, Hartlepool M.B., Boldon U.D. and Barnard Castle U.D. experienced particularly large percentage decreases (over 45%) which were comparable to those recorded in the six rural districts in the central and western portions of the County. On the other hand, the rural districts of Easington, Sunderland and Darlington were notable for their relatively low rates of decrease, although this anomaly could conceivably be explained in terms of proximity to the relatively large reservoirs of infection at Sunderland and Darlington respectively.

MEAN ANNUAL INCIDENCE OF RESPIRATORY TUBERCULOSIS
IN COUNTY DURHAM
1961-1965



NOTIFICATIONS
Per 100,000



□ 1,000 Persons

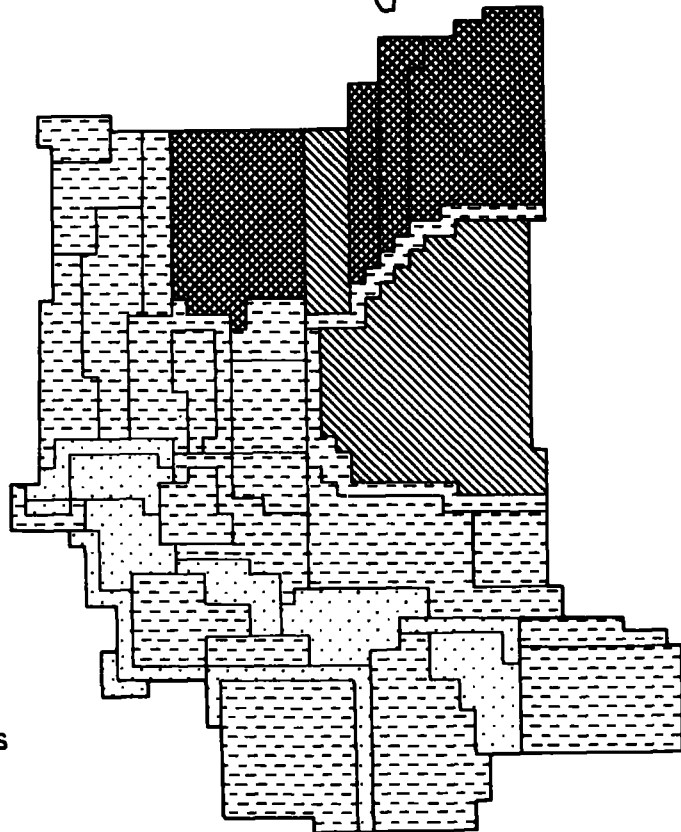


Figure 5.6.

Mean Annual Notification Rates for Respiratory Tuberculosis in County

Durham 1961-65

GATESHEAD C.B.
(78)

HEBBURN U.D.
(88)

SOUTH SHIELDS C.B.
(75)

SUNDERLAND C.B.
(51)

CONSETT U.D.
(42)

TYNESIDE

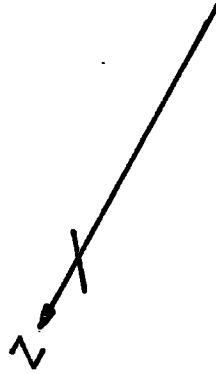
BISHOP AUCKLAND U.D.
(40)

HARTLEPOOL M.B.
(38)

STOCKTON M.B.
(37)

DARLINGTON C.B.
(37)

TEESSIDE



NOTIFICATION RATES per 100,000

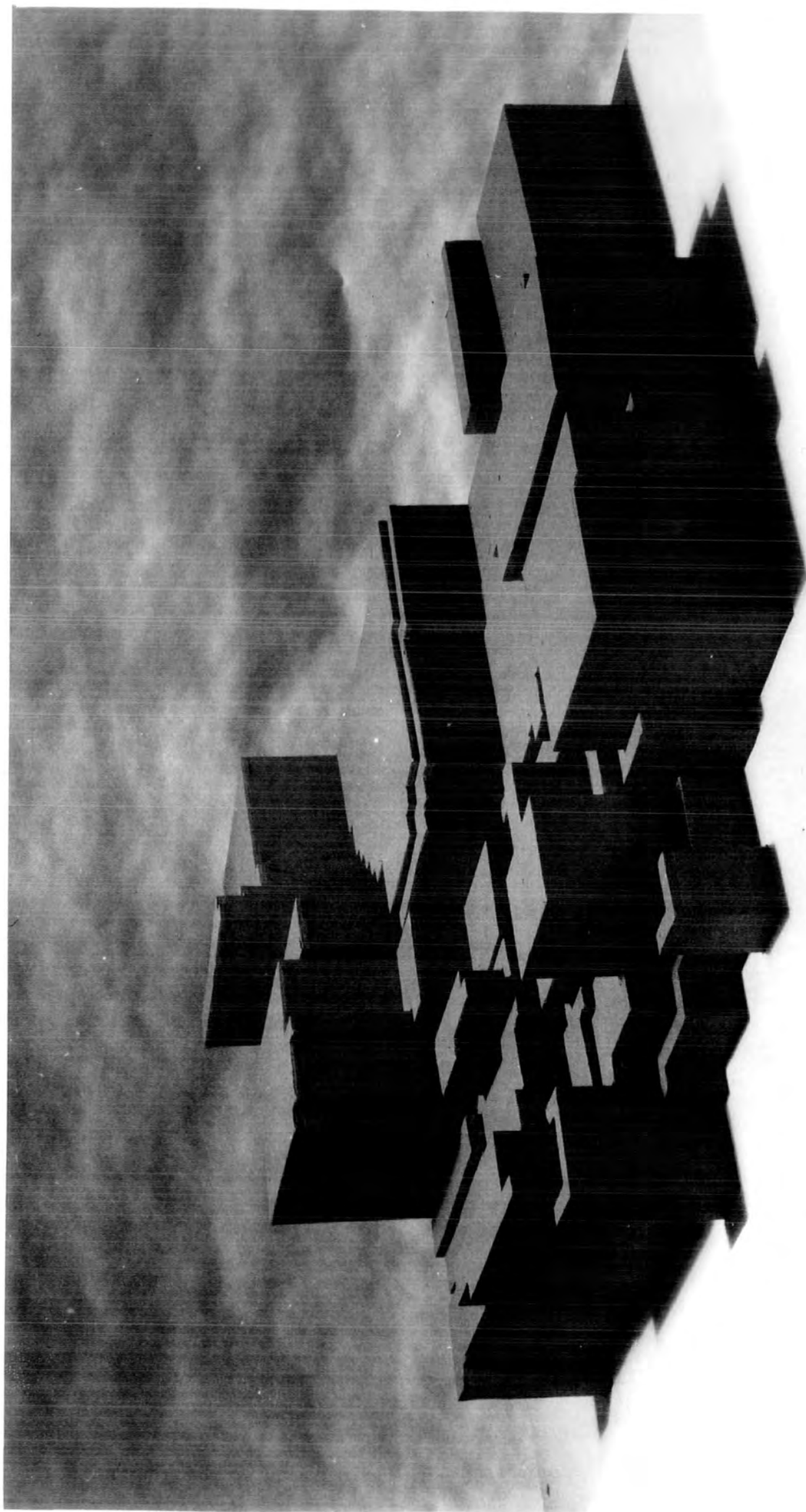


Figure 5.7.

5.4.2. Spatial aspects of the incidence of respiratory tuberculosis

Reference to figure 5.6. demonstrates the overall situation of South Tyneside as having greatest incidence of respiratory tuberculosis in County Durham. The demographic map in particular, and also the epidemograph representation figure 5.7., indicate the true significance of Tyneside as the infection reservoir. By comparison, even the foci on Wearside and Teesside must be considered as purely secondary in nature.

Hebburn U.D. and Jarrow M.B. with mean annual notification rates of 89 and 82 per 100,000 for the period 1961-5, respectively, recorded the highest absolute incidence rates in the County. Nevertheless, the sheer 'volume' of infection experienced in the neighbouring county boroughs of Gateshead and South Shields must not be under-estimated. (See figures 5.6. and 5.7.)

In comparison, the predominantly rural areas to the south of Tyneside recorded surprisingly low levels of incidence, with notification rates in the order of one-fifth those reported from Tyneside.

When the distribution of notifications is viewed on an annual basis for the five year period (figure 5.8.) the idea of relative simplicity of distribution suggested by figure 5.6. is to a certain extent dispelled. Thus, although in each of the five maps the area of South Tyneside maintains its overall supremacy in terms of incidence, the individual local authorities concerned experienced wide variations in incidence from year to year. For example, whereas Jarrow M.B. recorded an annual rate of 118 per 100,000 in 1963, the corresponding rates for 1962 and 1965 were substantially lower at 62 and 45 respectively.

The series of maps in figure 5.8. also helps to emphasise the general amelioration in levels of incidence that took place during the period. In 1965, only Gateshead C.B. returned a notification rate in

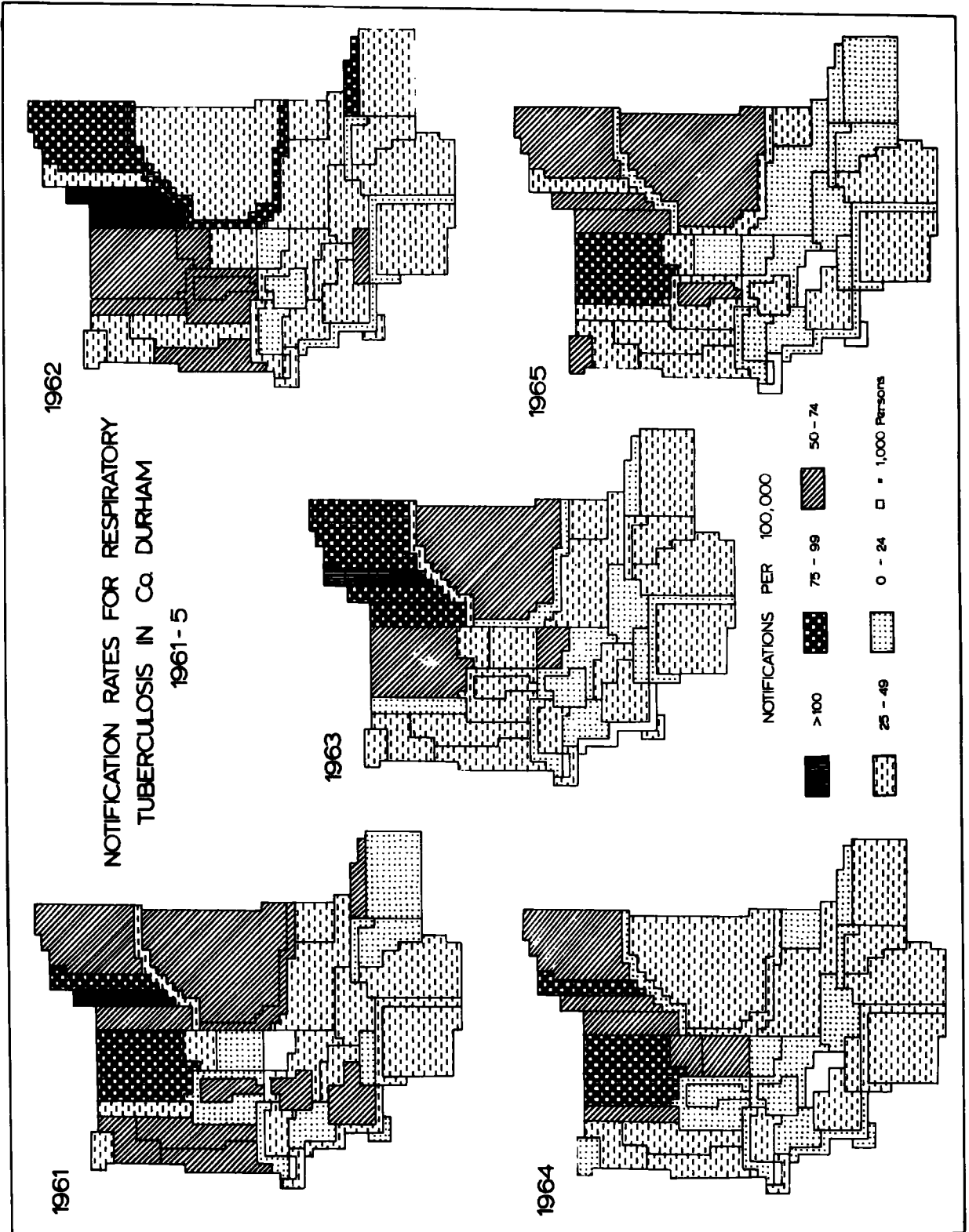


Figure 5.8.

excess of 75 per 100,000, whereas in 1962 no less than six individual local authorities were in this category. Similarly, the zone of particularly low levels of incidence (less than 25 per 100,000) in 1965 was seen to be a more or less consolidated area in the south and central portion of the County, comprising 18 of the County's forty local authorities. In 1962, on the other hand, only six local authorities recorded such low levels of incidence (under 25 per 100,000) and their distribution within the County did not suggest any marked tendency towards spatial consolidation.

5.5. Non-respiratory tuberculosis in County Durham

5.5.1. Temporal aspects

Figure 5.4. indicates that, for the five year period under consideration, the monthly incidence of non-respiratory tuberculosis in County Durham did not appear to fluctuate substantially from month to month, nor was it possible to discern a significant trend in the statistics as had been possible in the case of respiratory tuberculosis (see section 5.3.1. *supra*). This situation may be explained partly by the small number of cases notified - 479 for County Durham between 1961 and 1965 - and partly in terms of the multiplicity of forms of non-respiratory tuberculosis encountered in general practice. However, since a similar regime was seen to exist in the case of England and Wales as a whole (figure 5.3.), it would appear unlikely that the County Durham situation is particularly unusual in this respect.

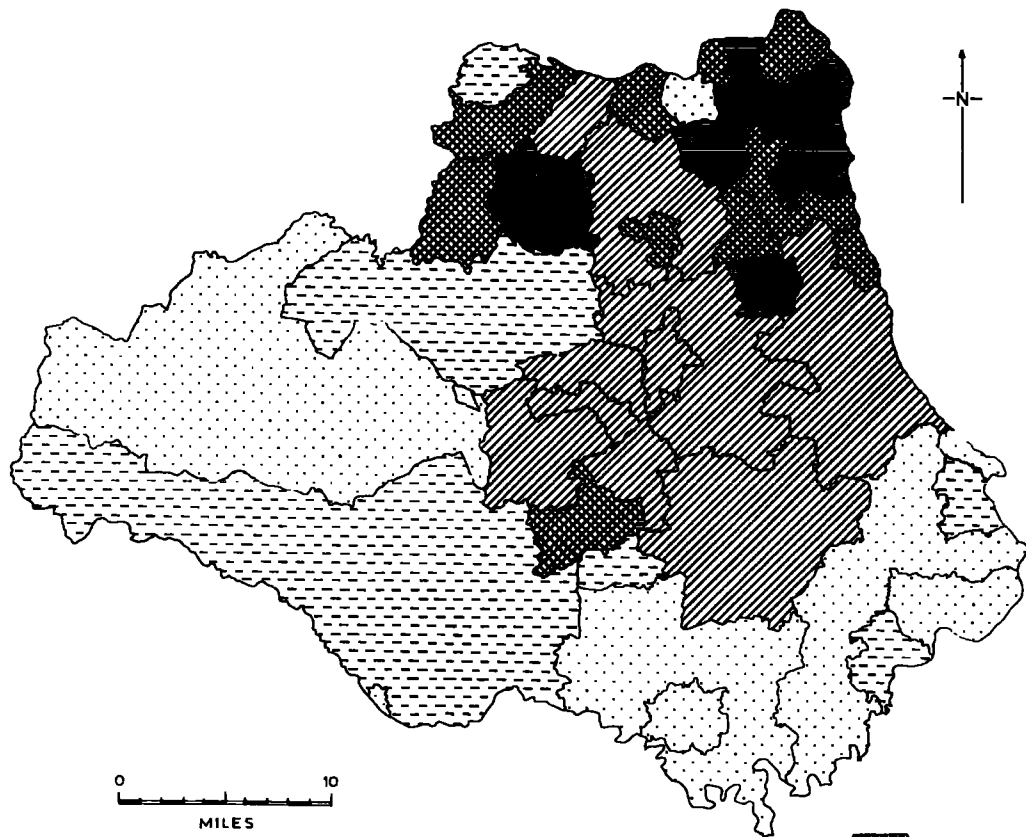
Table 5.5. shows that the mean annual number of reported cases for the County was a little under 100, yielding an overall case rate of 6.8 per 100,000, which compared with a figure of only 5.3 per 100,000 for England and Wales as a whole. The annual fluctuations of notifications for all three local authority categories appeared to be of an entirely random nature, since none of these approached any measure of statistical significance.

	1961		1962		1963		1964		1965	
	Cases	C.R.	Cases	C.R.	Cases	C.R.	Cases	C.R.	Cases	C.R.
County Boroughs	34	6.1	40	7.2	37	6.6	43	7.7	39	7.0
Urban Districts	56	8.9	36	5.7	37	5.9	50	8.0	37	5.9
Rural Districts	12	4.1	13	4.4	12	4.1	14	4.8	19	6.5
County Total	102	6.9	89	6.0	86	5.8	107	7.2	95	6.4

Table 5.5. Annual notifications and case rates per 100,000 for non-respiratory tuberculosis in County Durham, by major local authority categories, 1961-5.

NON-RESPIRATORY TUBERCULOSIS

MEAN ANNUAL NOTIFICATION RATES
By Local Authority - 1961-65



NOTIFICATIONS PER
100,000 PERSONS

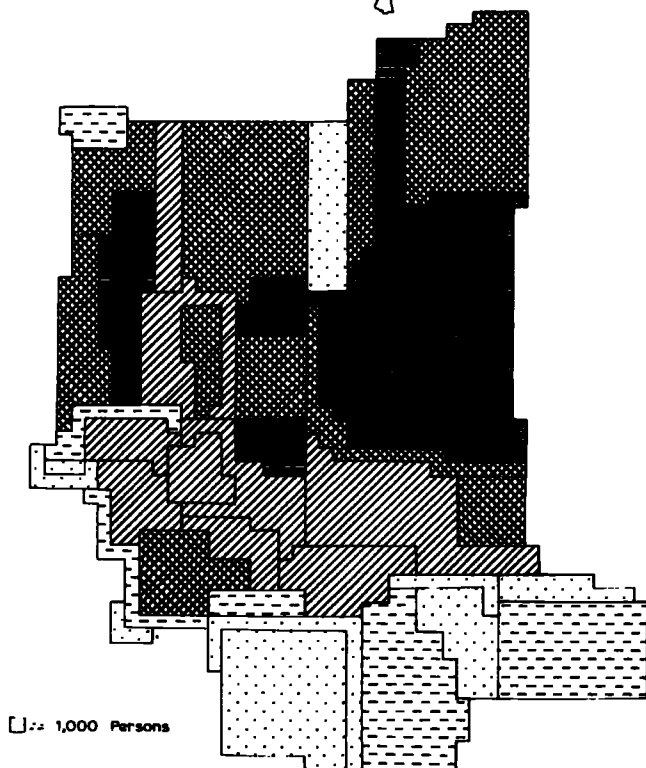
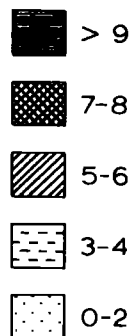


Figure 5.9.

From the available evidence, it would appear that although substantial inroads may have been, and are still being, made into the reservoirs of pulmonary tuberculosis, there appears to be little indication either at the national or the local county level that similar advances are being achieved in the case of all other forms of tuberculosis.

5.5.2. Spatial aspects of the incidence of non-respiratory tuberculosis

As in the case of the respiratory form of the disease, the northern parts of the county exhibited the highest notification rates for tuberculosis, other forms. The whole of Wearside and Tyneside (with the exception of Felling U.D.) emerged as a consolidated area of particularly high incidence in the north-east of the County, while a secondary focus in the north-west, centred on Stanley U.D., was also discernible (figure 5.9.).

In contrast, the south-east corner of the county, including the Hartlepoons, north Teesside and Darlington, together with the rural areas of west Durham, showed uniformly low notification rates (less than 4 per 100,000). The remainder of the county, comprising much of central and eastern Durham, experienced intermediate levels of morbidity.

Despite the relatively small numbers of non-respiratory tuberculosis notifications involved, the marked spatial variations in the disease pattern (figure 5.9.) defied explanation in terms of purely random fluctuations. Moreover, the basic similarity between this distribution and the one shown in figure 5.6. tended to lend added significance to the spatial variations already noted in the case of the respiratory forms of the disease.

5.6. Aetiological factors

A considerable number and variety of factors have been invoked to explain the distribution of tuberculosis, and in particular the

pulmonary form of the disease. Appendix C attempts a brief resumé of the most significant contributions to date in the field of causation. From the evidence presented, it would appear that the distribution of tuberculosis is principally a function of particular social and economic conditions rather than the product of the natural or physical environment. It was therefore decided to restrict the present study to a consideration of the effects of a selected range of socio-economic indices as follows:-

1. Proportion of the economically active male population in socio-economic group 1.
2. Proportion of the economically active male population in socio-economic group 2.
3. Proportion of the economically active male population in socio-economic group 3.
4. Proportion of the economically active male population in socio-economic group 4.
5. Proportion of the economically active male population in socio-economic group 5.
6. Average number of persons per acre.
7. Percentage of households living at less than $\frac{1}{2}$ person per room.
8. Percentage of households living at between $\frac{1}{2}$ and $\frac{3}{4}$ persons per room.
9. Percentage of households living at between $\frac{3}{4}$ and 1 person per room.
10. Percentage of households living at 1 person per room.
11. Percentage of households living at between 1 and $1\frac{1}{2}$ persons per room.
12. Percentage of households living at more than $1\frac{1}{2}$ persons per room.
13. Percentage of households having the exclusive use of 4 household arrangements (see factors 14-21).
14. Percentage of households without the use of a fixed bath.
15. Percentage of households sharing a fixed bath.

16. Percentage of households without a hot water tap.
17. Percentage of households sharing a hot water tap.
18. Percentage of households entirely without a water closet.
19. Percentage of households sharing a water closet.
20. Percentage of households entirely without the use of a cold tap.
21. Percentage of households sharing a cold water tap.

All the above indices are readily available in a quantitative form, and in each case the values for individual local authority areas are derived from official census material for 1961 (Registrar General 1964, and 1966). The data represent indirect but comparatively objective measures of less readily observable and more intangible characteristics such as poverty, housing conditions and general living standards. In previous studies, such characteristics have been gauged in an essentially subjective fashion. For example, Bradbury, in defining his term insanitary dwelling, employs no less than six separate criteria; all of which required a considerable degree of subjective assessment. (Bradbury 1933).

Factors 1-5 are measures of socio-economic status of the economically-active male population between 15 and 65 years. By implication, this type of index may be used to define the total population through the household or family unit. Although socio-economic status relates essentially to the mode of occupation - manual or non-manual (professional); skilled or unskilled, etc. - it is nevertheless an extremely useful indicator of the relative conditions experienced at both home and work.

Factors 6-12 inclusive are all indices of density. As such they provide a useful measure of the risk of infection both within and outside the home environment. From an epidemiological point of view it is not

unreasonable to assume that as densities become greater the potential number of contacts between individuals will also increase. As such density may be seen to be an extremely important predispositional factor in facilitating the transmission of infection. On the other hand, density and in particular overcrowding, must also be regarded as an additional, though indirect, index of a number of other criteria, such as general living standards and housing conditions.

Factors 13-21 inclusive are all additional indices of living conditions, which may be employed, not only to define the age and condition of housing in an area, but also as a further guide to the social and economic circumstances of the occupants themselves.

A further group of factors, concerned with the age-structure of the population by local authority areas, was also included for initial consideration. However, since none of these additional factors was subsequently shown to have any significant bearing on the geographical distribution of tuberculosis within County Durham, it was decided to exclude them from further investigation and discussion.

5.6.1. A simple correlation analysis

The twenty-one factors defined above were tabulated for the forty local authority divisions of County Durham, and subsequently correlated with the corresponding values for tuberculosis incidence. In all, seven different measures of tuberculosis were considered. These were a) the mean annual notification rate for respiratory tuberculosis between 1961 and 1965, b)-f) the annual notification rates for respiratory tuberculosis for the five individual years, and g) the mean annual notification rates for non-respiratory tuberculosis between 1961 and 1965 (see figures 5.6., 5.8. and 5.9. respectively). The resultant coefficients of correlation (obtained by using the product-moment method) together with an indication of the statistical significance of each are given in table 5.6.

FACTOR	RESPIRATORY TUBERCULOSIS						Tuberc. Non-Resp. Not. Rate 1961-65
	Mean Ann. Not. Rate 1961-65	1961	1962	1963	1964	1965	
1. Socio-Econ. Gr. 1	-0.05	0.01	0.03	-0.16	-0.10	0.04	-0.15
2. Socio-Econ. Gr. 2	0.24	0.24	0.07	0.10	0.19	0.32*	-0.23
3. Socio-Econ. Gr. 3	0.62***	0.36*	0.60***	0.59***	0.54***	0.50***	0.36*
4. Socio-Econ. Gr. 4	-0.46**	-0.46	-0.38*	-0.31*	-0.38*	-0.37*	0.24
5. Socio-Econ. Gr. 5	0.57***	0.53***	0.45**	0.55***	0.45**	0.39*	-0.12
6. Density per Acre	0.69***	0.54***	0.52***	0.69***	0.53***	0.63***	0.15
7. % less than $\frac{1}{2}$ p.p.r.	-0.36*	-0.20	-0.36*	-0.34*	-0.31	-0.30	-0.48**
8. % $\frac{1}{2}$ - $\frac{3}{4}$ p.p.r.	-0.40*	-0.27	-0.42**	-0.41**	-0.30	-0.24	-0.39*
9. % $\frac{3}{4}$ -1 p.p.r.	-0.53***	-0.44**	-0.48**	-0.53***	-0.37*	-0.36*	-0.45**
10. % at 1 p.p.r.	0.20	0.03	0.29	0.14	0.14	0.25	0.38*
11. % 1- $1\frac{1}{2}$ p.p.r.	0.46**	0.32*	0.46**	0.42**	0.36*	0.37*	0.42**
12. % over $1\frac{1}{2}$ p.p.r.	0.56***	0.47**	0.44**	0.55***	0.42**	0.48**	0.61***
13. % with 4 Arrangements	-0.08	-0.11	0.00	-0.17	-0.05	0.02	-0.37*
14. Without fixed bath	-0.08	0.10	0.01	0.17	0.05	-0.04	0.39*
15. Sharing fixed bath	0.11	0.13	-0.06	0.14	0.02	0.28	0.03
16. Without hot tap	0.21	0.20	0.13	0.27	0.17	0.09	0.29
17. Sharing hot tap	0.14	0.11	-0.04	0.17	0.07	0.30	0.06
18. Without W.C.	-0.34*	-0.28	-0.24	-0.32*	-0.31*	-0.28	-0.00
19. Sharing W.C.	0.37*	0.31*	0.18	0.46**	0.28	0.37*	0.30
20. Without cold tap	0.28	0.32*	0.12	0.35*	0.23	0.15	0.06
21. Sharing cold tap	0.23	0.20	0.04	0.28	0.14	0.35*	0.19

*** Very Highly Significant, $P < 0.001$

** Highly Significant, $0.01 > P > 0.001$

* Significant, $0.05 > P > 0.01$

Table 5.6. Coefficients of Correlation between Notification Rates per 100,000 for tuberculosis, and selected social indices by Local Authority Areas in County Durham, 1961-5.

Second Degree Relationship between Respiratory Tuberculosis & Socio-Economic Groups in County Durham (By Local Authorities)

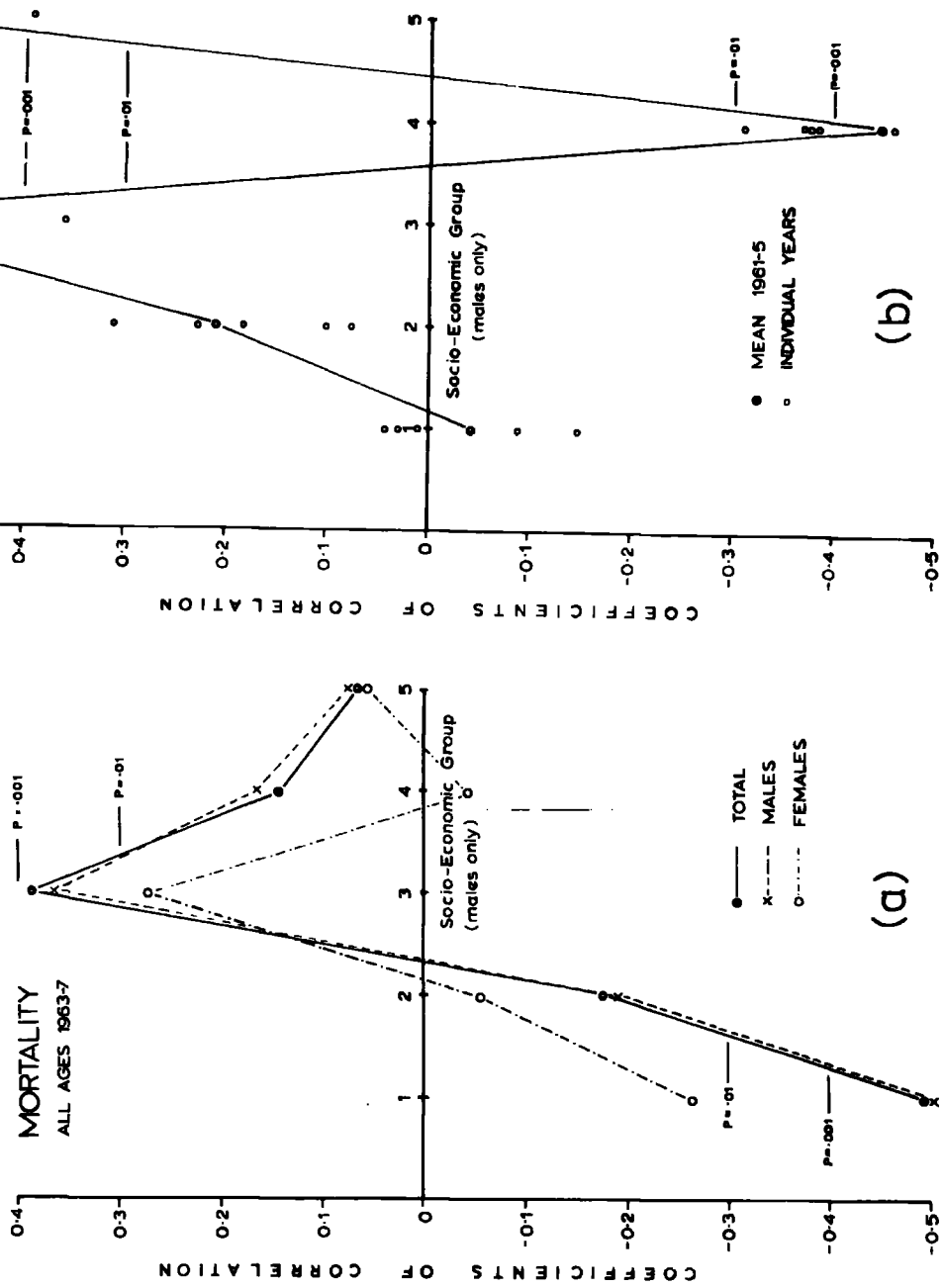


Figure 5.10.

5.6.1.1. Socio-economic factors (1-5).

In the case of respiratory tuberculosis, the coefficients of correlation between socio-economic status and the mean annual notification rates (1961-5) were shown to be significant for groups 3, 4, and 5. Two of these, groups 3 and 5, exhibited strong positive correlations, whilst group 4 (semi-skilled manual workers) rather surprisingly showed a strong negative correlation. Figure 5.10.(b) summarises these findings in a more graphical form than table 5.6. In particular, the dramatic swing from a positive association in the case of groups 3 and 5 to an equally strong negative association for group 4 is clearly demonstrated. In addition, the lack of statistical association in the case of groups 1 and 2 is also displayed.

When the situation is analysed for individual years, the positive correlation for socio-economic group 3 (skilled manual workers) is seen to be remarkably consistent ($p < 0.001$) with the exception of 1961. In contrast, the corresponding coefficients of correlation for groups 4 and 5 tend to fluctuate more widely, although still retaining a substantial measure of statistical significance.

A similar analysis of mortality statistics which were collated in connection with section III of this thesis, revealed a substantially different situation than in the case of notifications. Figure 5.10.(a) provides a visual representation of the coefficients obtained by correlating socio-economic status and standardised mortality ratios from respiratory tuberculosis for the forty local authority areas of County Durham between 1963 and 1967. As in the case of figure 5.10.(b), socio-economic group 3 (skilled manual workers) exhibited a significant positive correlation coefficient. However, it is surprising to note that both groups 4 and 5 failed to achieve any measure of statistical significance in their association with the mortality rates. On the other hand, socio-economic group 1 displayed a strong negative relationship, which was statistically speaking highly significant ($p < 0.001$).

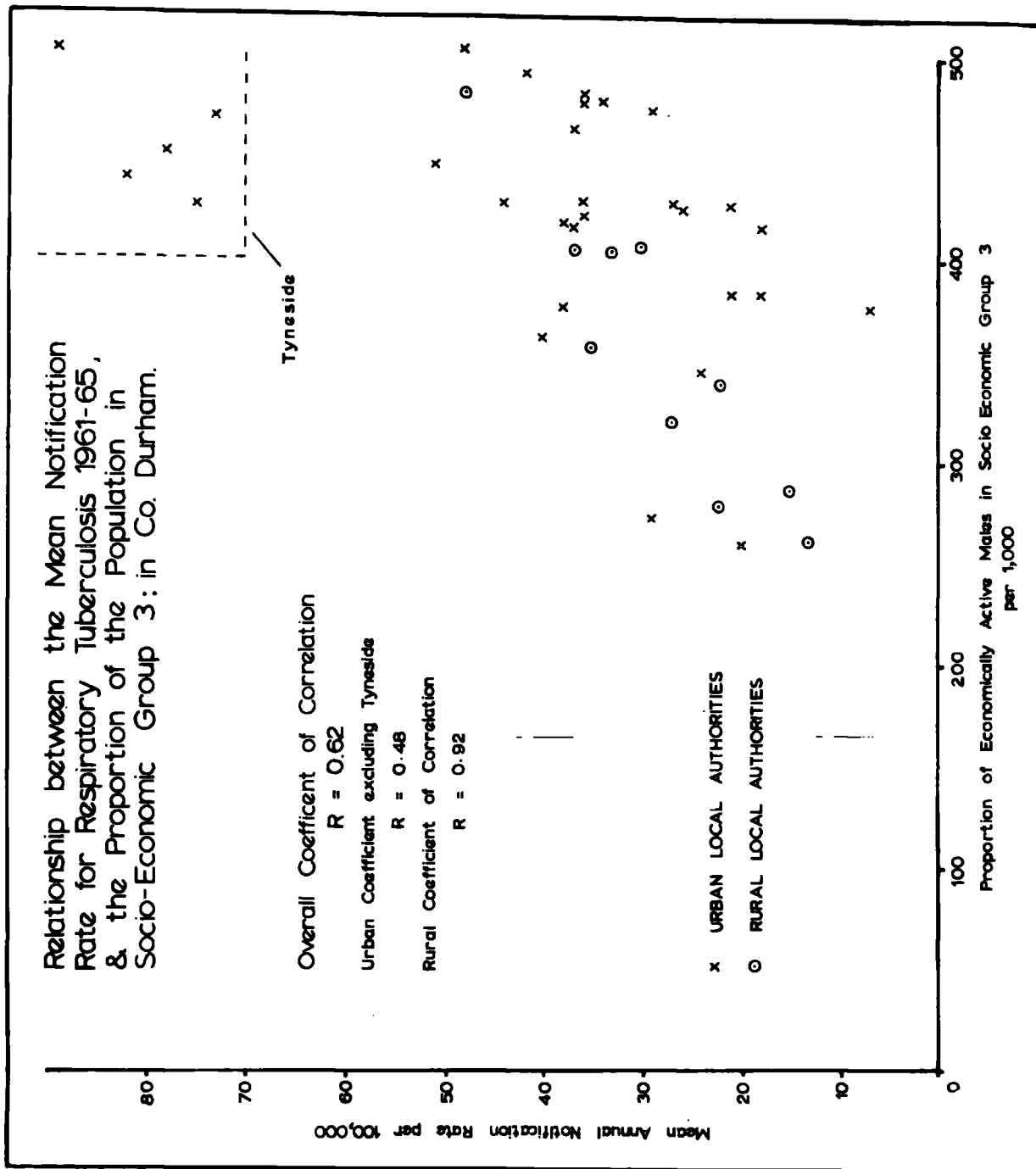


Figure 5.11.

The low coefficients of correlation in the case of females (figure 5.10.(a)) may be explained largely in terms of the small numbers of deaths from tuberculosis that occur amongst women. However, it is interesting to note that the overall regime of coefficients is nevertheless similar in both sexes.

Figure 5.11. shows the mean annual notification rates for respiratory tuberculosis plotted against the proportion of economically active males in socio-economic group 3 for the forty local authority areas of the County. From the diagram a number of extremely interesting facts emerge. Firstly, the five local authorities in South Tyneside are considerably detached from the other points of the scatter. Secondly, when the ten rural districts are considered in isolation, the regression between the two factors is seen to be particularly significant, despite the small numbers of notifications involved. The positive coefficient of correlation ($R = + 0.92$) was seen to be very highly significant ($p < 0.001$, $df. = 8$). By comparison, the corresponding association for the urban areas, excluding the five South Tyneside local authorities was considerably less well-defined than in the case of the rural districts, although still statistically significant ($R = + 0.48$, $0.05 > p > 0.01$ for $df. = 23$).

Although the above results for County Durham appear to concur quite favourably with the findings of previous workers in this field, one or two minor anomalies do emerge which deserve a measure of further comment and explanation.

In the first place, the significance of the relationship involving socio-economic group 3 workers is far greater than that noted by either Merrett (1959) or Benjamin (1953). In both the latter cases, it was the relationship involving socio-economic group 5 workers which yielded the most significant positive association. Secondly, it was rather surprising

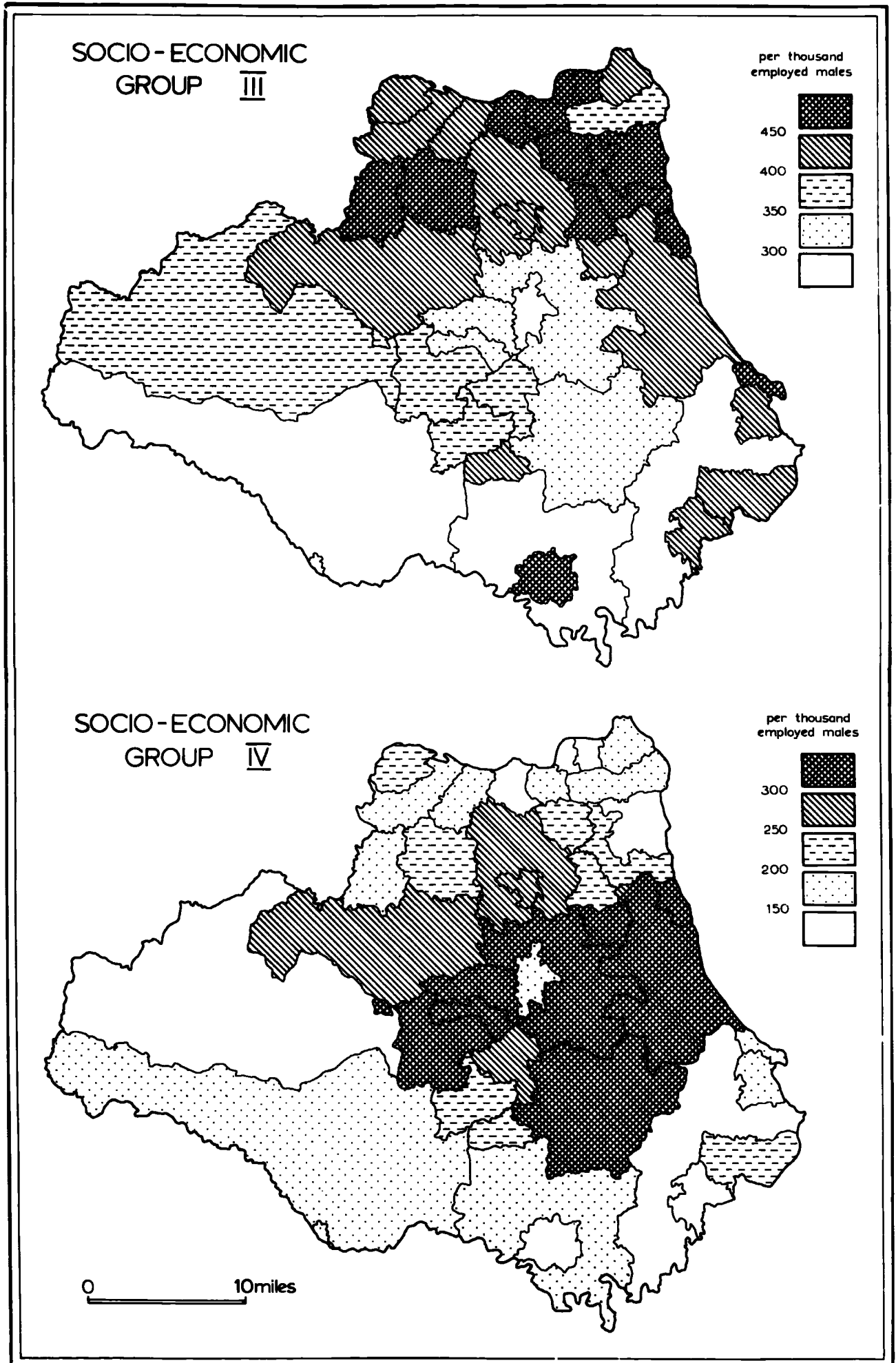


Figure 5.12.

to discover that the second-degree relationships involving notification and mortality rates (figure 5.10.(b), and figure 5.10.(a) respectively) displayed essentially different regimes. And thirdly, the negative relationship noted in the case of socio-economic group 4 (semi-skilled workers) was substantially more significant than the similar trend observed by Merrett in Northern Ireland (Merrett 1959). This seemingly anomalous situation may be explained at least partly in terms of a) the spatial distribution of the various socio-economic groups within the County, and b) the type of industrial environment with which each is predominantly associated.

The majority of local authority areas exhibiting a high proportion of group 3 workers (skilled manual) amongst their employed male population are located in the long-established industrial areas of the County (figure 5.12) - notably Tyneside, Wearside and Hartlepool. In these areas, many industrial concerns, including chemical and engineering works, together with ship building and repair yards, are still confined, by inertia, to their original site. Many of the buildings are outmoded, cramped and ill-ventilated; and as a result the working conditions experienced in particular industries especially on Tyneside are particularly unfavourable as judged by modern standards. The significance of such conditions in the dissemination of the tubercle bacillus has been demonstrated by such workers as Collis (1923). In addition, the concomitant age and condition of much of the housing in these same areas have, despite the effects of the extensive redevelopment programmes of the last decade, meant that a significant proportion of the skilled population has been obliged to live in sub-standard housing. This provided a further source of infection amongst the skilled population, which constitutes between forty and fifty per cent of the economically active male population in these areas.

In contrast, the areas with the highest proportion of semi-skilled workers (group 4) are located predominantly in central Durham, away from the major urban concentrations (figure 5.12.) - notably Easington, Durham and Sedgfield rural districts; and Brandon, Crook and Hetton urban districts. With the decline of mining in these areas, this particular sector of the working population is becoming absorbed into the growing number of new light industries which are appearing on industrial sites throughout the County. Situated away from the main reservoirs of tuberculosis infection, and enjoying considerable advantages in both housing and working conditions, it is perhaps not surprising that many of these areas are experiencing the most rapid declines in notification rates (see section 5.4.1. supra). This also helps to explain the unexpectedly high negative correlation coefficient noted in the case of socio-economic group 4 (figure 5.10.).

When socio-economic status is correlated with the mean annual notification rates for non-respiratory tuberculosis, it was discovered that only the relationship involving group 3 achieves any measure of statistical significance. Even on this partial basis, however, the repetition of a significant positive coefficient of correlation in this case ($R = + 0.36$, $0.05 > p > 0.01$) lends added support to the corresponding results obtained for respiratory tuberculosis.

5.6.1.2. Density factors (6-12)

Of all the 21 factors considered in the present correlation analysis, factor 6, the number of persons per acre, displayed the highest degree of correlation with the mean annual notification rate for respiratory tuberculosis between 1961 and 1965 ($R = + 0.69$, $p < 0.001$). Furthermore, when the situation was analysed more closely, it was noted that the coefficients obtained for each of the five years were all positive, and statistically speaking very highly significant ($p < 0.001$).

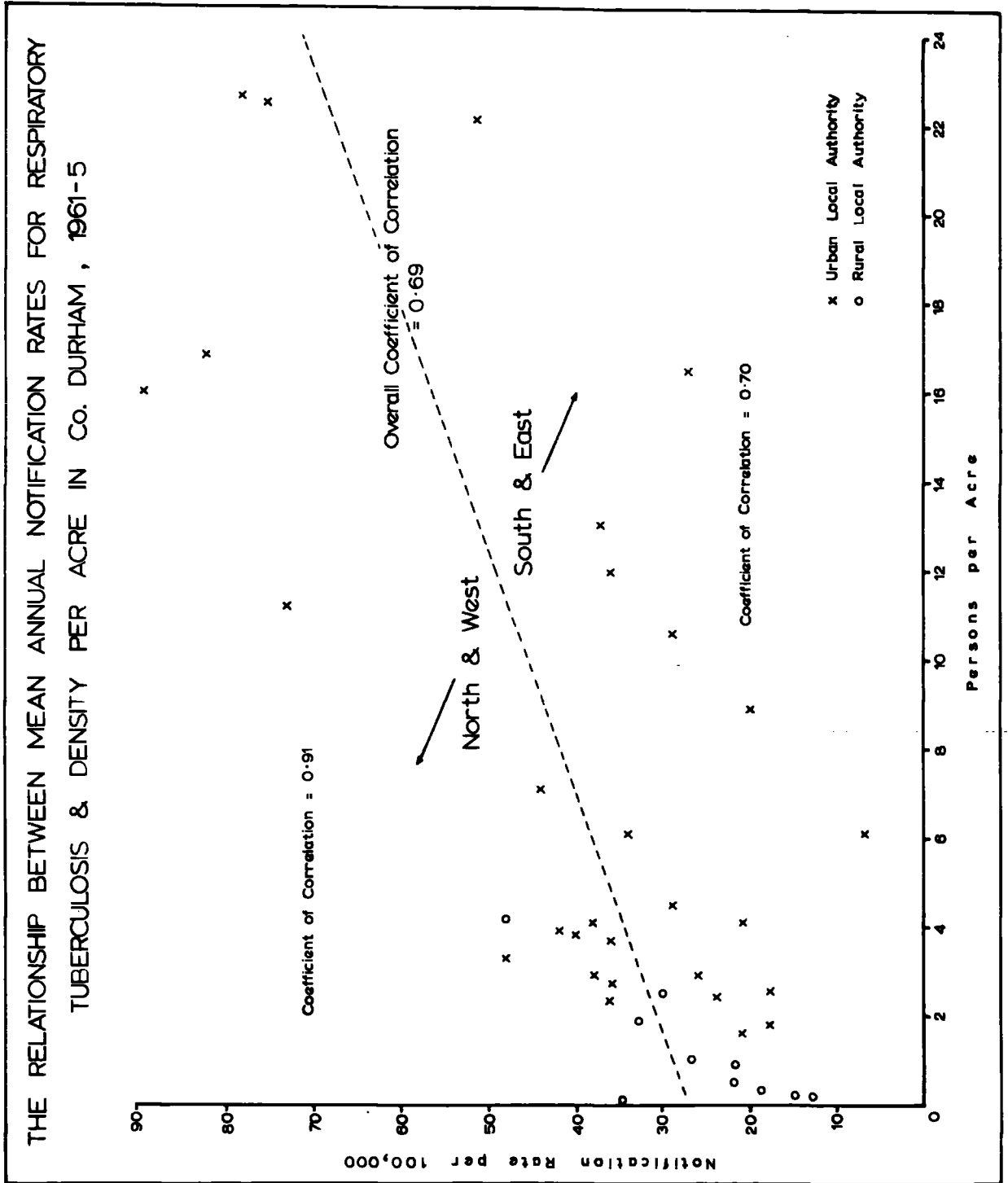


Figure 5.13.

Figure 5.13. indicates graphically the statistical relationship which exists between the mean annual notification rates (1961-5) and density per acre, by local authority in County Durham. The overall statistical association between the two factors is readily apparent. However, when the scatter is analysed further in terms of the geographical location of individual points, a well-defined spatial pattern emerges. All those points situated above the line in figure 5.13. were found to be local authorities in the north and west of the County, whilst those below the line represented local authorities in the south and east of Durham. By undertaking such an arbitrary division purely in terms of geographical criteria, it was subsequently discovered that the degree of association between the two factors under consideration was further enhanced, particularly in those local authorities above the line ($R = 0.91$, $p < 0.001$, $df 15$) - i.e. to the north and west of the County. Furthermore, it may be noted from figure 5.13. that the slope of the regression for the points above the line was substantially steeper than the corresponding regression for the points below the line. From this latter observation it would appear that the influence of this particular density factor is effectively greater in and around what may be defined the reservoir areas for the disease.

Turning to a consideration of the effect of living densities (expressed in terms of persons per room) upon the incidence of respiratory tuberculosis, it may be seen that although the individual results were not so consistent or significant as in the case of factor 6 above, they nevertheless yielded valuable insight into the causation and transmission of the disease.

Table 5.6. and figure 5.14. clearly demonstrate the strong statistical relationship which exists between the proportion of the population living at particular room densities and the corresponding notification

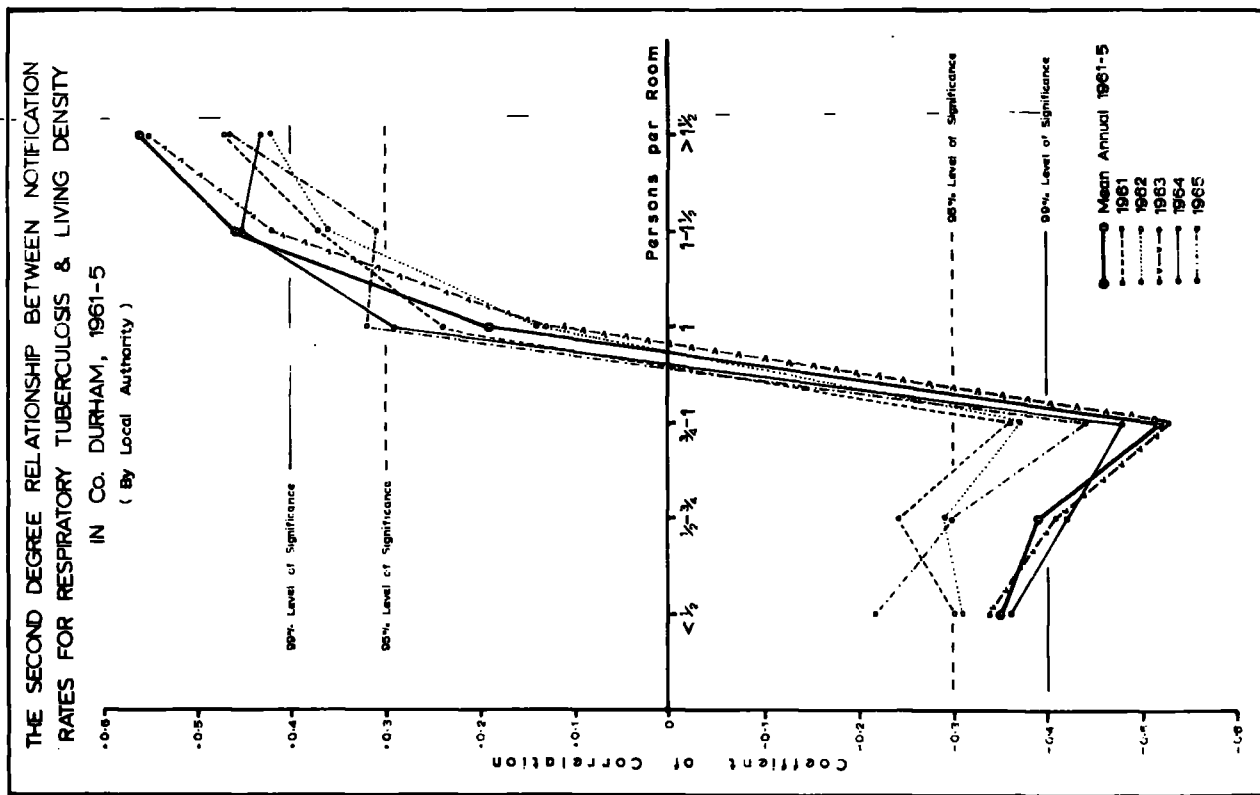


Figure 5.14.

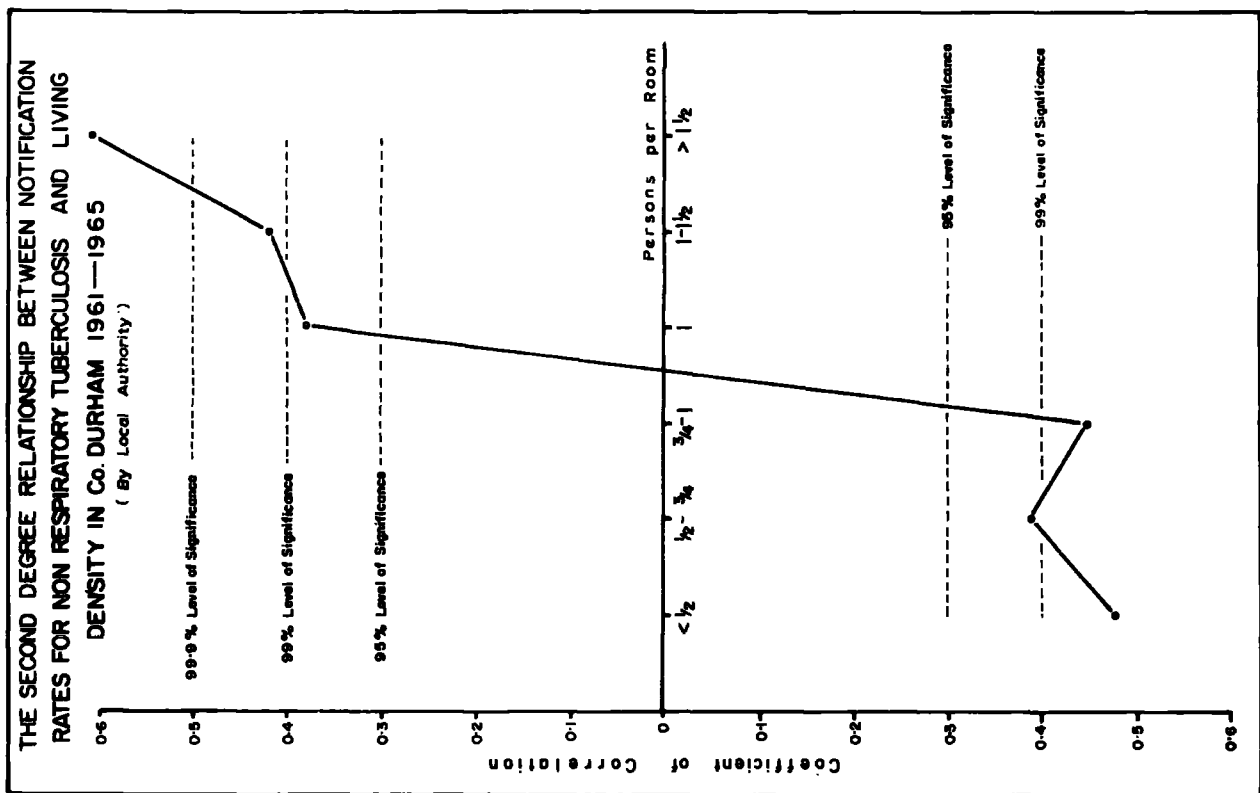


Figure 5.15.

rates for respiratory tuberculosis. In particular, the association involving the proportion of the population living in overcrowded conditions (more than $1\frac{1}{2}$ persons per room) was shown to be consistently positive and highly significant ($0.01 > p > 0.001$) for each of the five years under consideration. Similar positive, though less significant, relationships were seen to exist in the case of the categories containing one person, and one to one and a half persons per room respectively. In contrast, the coefficients of correlation obtained for the three categories with the lowest living densities - viz. under 1 person per room - were all negative and quite significantly so. This well-defined swing from a positive to a negative correlation at or around a threshold value of 1 person per room is an especially interesting phenomenon which should surely merit further investigation. It is true of course that when such a 'closed' data set is subjected to this type of correlation analysis involving all elements of the set, positive deviations of coefficients must by necessity be counter-balanced by other negative deviations. However, even allowing for this, the particular regime noted in figure 5.14. appears far too symmetrical to have been evoked by such a system of random compensations.

A similar relationship between living densities and notification rates was also seen to exist in the case of the non-respiratory forms of the disease. Indeed, in many ways the regime of correlation coefficients (figure 5.15.) was even more dramatic than in the previous example (figure 5.14.), despite the substantially smaller number of notifications involved. For each of the six categories of living density, the coefficients of correlation obtained proved to be statistically significant ($p < 0.05$). Once again, the value of 1 person per room emerged as the apparent threshold between the positive and negative associations.

5.6.1.3. Indices of living conditions (factors 13-21)

Although Stein (1952) was of the opinion that ".....housing conditions form the largest single factor in the 'complex' (of causation)", the present investigation failed to achieve such convincing results. This may be explained partly in terms of the larger and therefore less homogeneous units employed in the collation and analysis of the data - viz. local authority areas as opposed to wards and parishes used by Stein - and partly by the relatively small percentage values of many of the factors in this group. With regard to this latter point, it is perhaps worth remembering that only in the case of factors 13 and 14 (the percentage of households with the exclusive use of four household arrangements, and the percentage of households without a fixed bath, respectively) was more than 15% of the population of individual areas under consideration at any given time. That is to say, the majority of these indices were in fact only representative of small minority groups of households within the County.

Nevertheless, despite the above limitations, a number of extremely interesting statistical relationships emerged, between the spatial patterns of this particular group of indices and the geographical distribution of notification rates for tuberculosis. (Table 5.6.)

In the case of the respiratory form of the disease, the most significant and consistent relationship was the positive correlation noted between the notification rates for tuberculosis and the percentage of households sharing water closets. This particular observation could be interpreted in one of two ways. Firstly, it might suggest that the actual process of sharing such facilities was directly concerned with the transmission of the tubercle bacillus. A shared water closet would result in the gradual decline in the general hygienic standards that might otherwise have been maintained by a single household. This state of affairs would tend to enhance the possibility of the tubercle bacillus being fostered

in the water closet itself; thereby increasing the chances of cross-infection between family groups as well as between members of the same household. On the other hand, it might be argued that there is in fact no direct causal relationship in this case, but that the distribution of households sharing water closets is only one of many indicators of the crowded overall living conditions in which tuberculosis is particularly prevalent. As Bradbury (1933:48) comments, "Evidence of sanitation being a contributory cause of tuberculosis is not found, although the results are consistent with this hypothesis." Rather he considers that "The association observed between tuberculosis and insanitation can be completely explained by the greater poverty of tuberculosis families compelling them to live in houses which are relatively insanitary."

Rather surprisingly, the corresponding relationship involving the percentage of households completely without the use of a water closet is characterised by a negative correlation, which is consistent throughout the five year period and is significant in three cases. This rather spurious situation may be explained in terms of the higher proportion of dwellings in south and west Durham which still have outside sanitation (1961 figures). In this connection, the local authorities of Brandon, Tow Law, Crook, Bishop Auckland and Barnard Castle R.D. are particularly unfavourable, with more than 12% of the households without water closets.

In the case of factors 20 and 21, concerned with the availability of a cold water tap, the coefficients of correlation were consistently positive, and for individual years were seen to achieve at least a measure of statistical significance ($0.05 > P > 0.01$). However, as in the case of factors 18 and 19 above, it would appear extremely unlikely that the geographical distribution of shared cold water taps could itself have any direct bearing on the incidence of tuberculosis. Rather it would appear that this factor must be regarded as a further indicator of other unfavourable environmental circumstances more intimately connected with

the actual transmission of the disease.

In the case of the non-respiratory forms of the disease, the associations with factors 13 to 21 were seen to be somewhat less dramatic. In fact, only two of the coefficients of correlation were statistically significant (Table 5.6.). The first of these, factor 13, the percentage of households having the exclusive use of four 'arrangements', elicited a significantly negative relationship, which tended to suggest that over the County as a whole notification rates were lowest in those areas where household facilities (and, by implication, housing conditions in general) were of a higher standard. Conversely, the higher notification rates tended to occur most frequently in those areas where such household facilities were lacking. The only other factor exhibiting a significant coefficient of correlation was factor 14, the percentage of households entirely without the use of a fixed bath. In this case, the coefficient was positive and significant ($0.05 > p > 0.01$).

5.6.1.4. Additional factors considered⁽¹⁾

For 28 local authorities in the north and east of the County, a further five factors were investigated in relation to the distribution of notification rates from respiratory tuberculosis. These were concerned specifically with the condition of dwellings within the local authorities, measured in terms of age and rateable value. They were as follows:-

1. The number of slum dwellings cleared between 1955 and 1966, expressed as a percentage of the total number of dwellings in 1955.
2. The percentage of nineteenth century dwellings in 1951.
3. The percentage of dwellings with a rateable value of £30 or under.
4. The percentage of dwellings with a rateable value of £31 - £57.

(1) The data for the five factors considered in this section were kindly supplied by Dr. P. Shoebridge (1969) from his work on inter-war housing in the Tyneside area.

Factor	Mean Ann Not. Rate 1961-65	1961	1962	1963	1964	1965
1. Slums cleared 1955-66	0.52**	0.43*	0.25	0.58**	0.46*	0.45*
2. % dwellings pre-1900	0.36	0.35	0.17	0.35	0.26	0.40*
3. Rateable val. £30	-0.30	-0.31	-0.37	-0.16	-0.15	-0.32
4. Rateable val. £30-£57	-0.24	-0.26	-0.32	-0.03	-0.14	-0.27
5. Rateable val. £57	0.46*	0.43*	0.55**	0.18	0.34	0.46*

* Statistically significant.

** Statistically highly significant.

Table 5.7. Coefficients of correlation between notification rates from respiratory tuberculosis and specific indices of dwelling conditions in County Durham, 1961-65. (28 local authorities in the north and east of the county considered).

5. The percentage of dwellings with a rateable value in excess of £57.

Table 5.7. indicates the coefficients of correlation which were obtained using the product-moment method, when the five factors were compared with the corresponding notification rates from respiratory tuberculosis between 1961 and 1965.

It was discovered that the relationships involving the first factor (the proportion of slum dwellings cleared) was statistically speaking the most significant of the five. Moreover, the highly significant positive association, particularly in the case of the mean annual notification rate, appeared to concur most favourably with the findings already discussed in sections 5.6.1.1. - 5.6.1.3. above. A high rate of slum clearance is in itself an admission of an existing housing problem, and is indicative that unfavourable living conditions have been widespread for a considerable period of time. Under such circumstances, one might expect that the perpetuation of the disease would have been actively encouraged, thereby eliciting correspondingly high notification rates.

The degree of association noted in the case of the second factor (percentage of housing built before 1900) was considerably less, although the relationship was consistently positive. This tended to suggest that the absolute age of a dwelling was a less significant influence in determining the overall prevalence of the disease than many other criteria concerned with the condition of the dwelling or the availability of specific household amenities and facilities.

The coefficients of correlation obtained for factors 3-5, relating to the rateable values of dwellings, revealed that there was in fact a positive relationship between individual notification rates and the percentage of dwellings with a rateable value in excess of £57. In

contrast, areas possessing a high percentage of dwellings with a low rateable value (under £30) tended on average to experience lower notification rates from respiratory tuberculosis. This seemingly anomalous situation may be explained in terms of the considerable rural/urban differential of rateable values. This does not represent a conflicting element of causation, but merely reinforces the conviction that tuberculosis is a disease of urban living.

5.6.2 Multiple correlation analysis

During the initial investigation of the simple statistical relationships existing between the distribution of tuberculosis and certain social and economic factors (supra section 5.6.1.) it became increasingly apparent that most, if not all, of the factors were themselves causally interrelated. As a result, the effect of one particular factor may have become essentially duplicated in one or more of the other factors considered. Under these circumstances, it was deemed necessary to determine the extent and nature of this interdependence or duplication of factors in order to identify more precisely the most significant strands in the complex web of causation.

As an initial step, only the four most significant factors were abstracted from the matrix of simple correlation coefficients (section 5.6.1.supra) for consideration. These were subsequently subjected to a process of progressive factor compounding, by means of multiple regression analysis. A suitable computer programme was written for this purpose, incorporating four standard I.B.M. sub-routines.⁽¹⁾

By 'adding' factors together it was possible to appreciate the combined effect of two or more variables on the distribution of the

(1) A sample of the results output by this programme is provided in Appendix D, and a listing of the programme itself is presented in Appendix E.

dependent variable (respiratory tuberculosis). By comparing these results with those obtained by simple correlation techniques, the extent to which particular variables overlapped with one another could be conveniently gauged. This latter effect is what Krumbein (1959) terms 'duplication of information' already supplied by other independent variables.

Conventionally, the variable displaying the strongest degree of association with the dependent variable during analysis by simple correlation - in this case density per acre - is adopted as the basis for subsequent multiple regression, and then the remaining independent variables are combined with it in turn. However, as Krumbein points out, "the strongest variable itself may be influenced by other variables, and if the criterion of the reduction in the sum of squares of X_0 is not physically sound, even the apparently strongest variable may be showing a spurious effect" (1959:580). Under the present circumstances, however, the relevance of the factor of density per acre to the investigation of an infectious disease such as tuberculosis requires little or no justification. Indeed, the concept of 'critical' or 'threshold' density values for susceptibles has for a long time been fundamental to epidemiology (Hamer 1906, Kermack and McKendrick 1927, 1932, 1937 and 1939).

The simple correlation analysis revealed that the factor of density per acre accounted for just over 48% of the variation in the notification rates for respiratory tuberculosis in County Durham during the period 1961-65.⁽¹⁾ This meant that a little under 52% of the variation in the distribution remained to be explained in terms of 'other factors' and also the vagaries of chance. In the case of the other three factors under initial consideration, namely socio-economic-group 3; socio-economic-group 5; and the percentage of persons living at more than $1\frac{1}{2}$ persons per

(1) The percentage explanation of the distribution is equal to $R^2 \times 100$, where R is the coefficient of simple correlation.

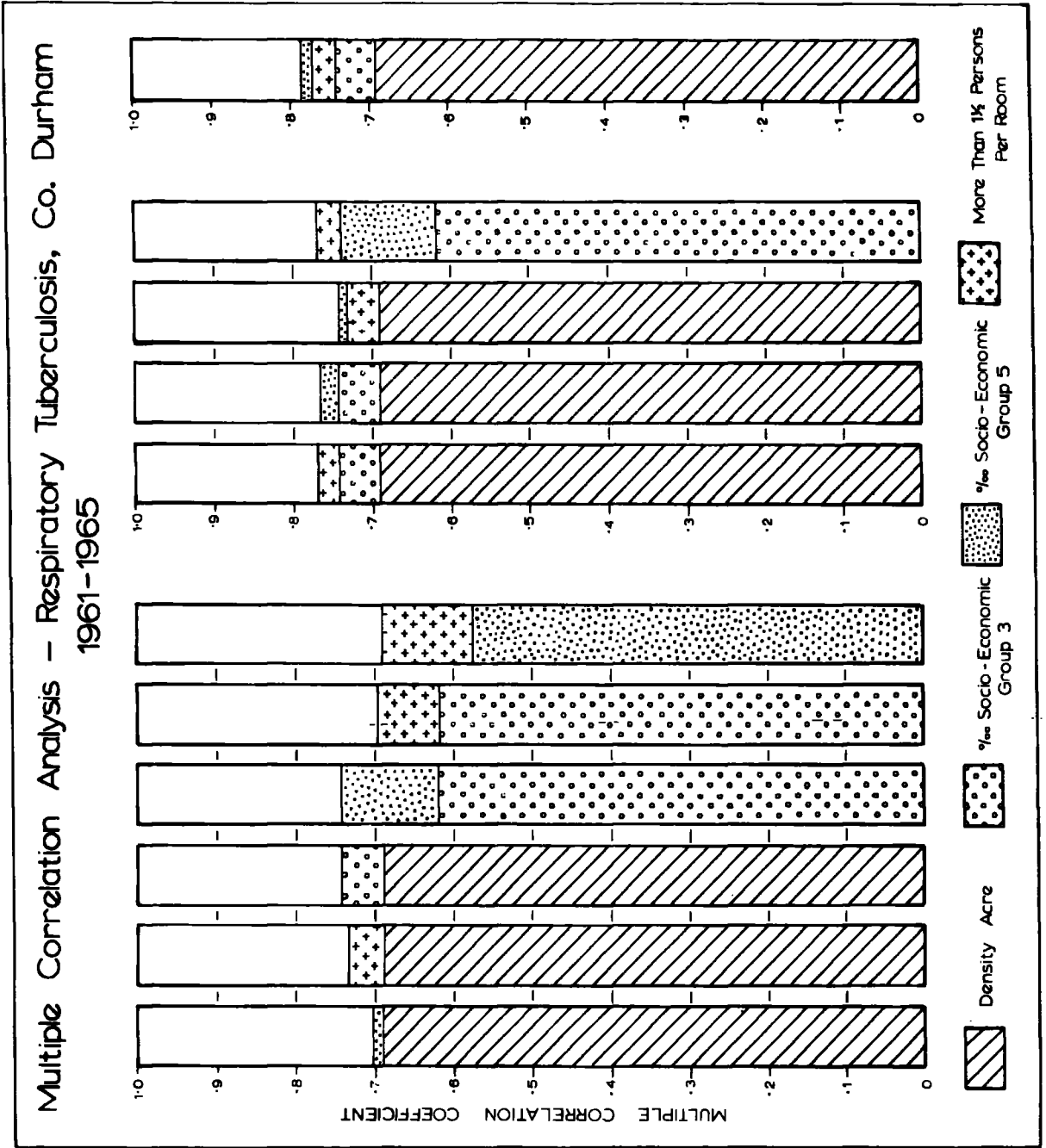


Figure 5.16.

room, the corresponding percentage explanations attributable to the simple correlation coefficients were substantially lower, at 38, 32 and 31 per cent respectively.

Figure 5.16. provides a diagrammatic representation of the progressive compounding involving the four individual factors. It may be seen that in the case of density per acre, the addition of a second factor contributes little to the overall percentage explanation - viz. 7% in the case of socio-economic group 3 and only 1% in the case of socio-economic group 5. This suggested that the bulk of the 'causal information' provided by the second factors had already been accounted for by the variation in the initial factor - density per acre.

By comparison, the compounding of factors other than density per acre produced a marked diminution in the degree of overlap or information duplication. Thus the multiple correlation coefficient obtained by combining the effects of socio-economic group 3 and socio-economic group 5 ($R = 0.74$) represented an increase of over 17% in the explanation of the distribution of respiratory tuberculosis compared with the simple correlation coefficient ($R = + 0.62$). This indicated that the two factors were making substantially different contributions to the overall explanation of the distribution of notification rates, despite the fact that the bulk of the explanation was in both cases still attributable to particular elements of causation held in common by the two factors.

The addition of a third factor added only slightly to the overall percentage explanation as calculated from the coefficient of multiple correlation. Indeed in no case was the increase in explanation seen to be in excess of 4%: a fact which further underlined the considerable interdependence of the four factors. Similarly, when all four factors were compounded, a further increment of only 3% was achieved. In this case, the overall coefficient of correlation was found to be 0.78, yielding an explanation of just over 61%, leaving a further 39% of the

variance to be explained in terms of additional factors.

Figure 5.17. shows the mapped residuals of this four-factor regression analysis. As may be seen, consolidated areas of significant residuals existed within the County. In particular, the local authorities of South Tyneside emerged as an area of high positive residuals, while the Hartlepool area in the south-east of the County yielded significant negative residuals. In addition, a number of more minor peaks and troughs of residuals were noted, although the majority of these could be explained in terms of purely random fluctuations.

The foregoing analysis tended to indicate that whereas the four factors considered so far had been successful in explaining the broader patterns of respiratory tuberculosis within County Durham, at the local level the influence of additional factors was more significant. For this reason, it was decided to continue the process of factor compounding a little further in an effort to establish whether or not the considerable polarisation of residuals noted in figure 5.17. could indeed be explained in terms of other factors.

Retaining the four initial factors (factors 3, 5, 6 and 12), each of the 17 other factors were incorporated in turn into the multiple regression, to determine the extent to which they contributed to the overall explanation of the distribution. From the subsequent computation factor 18 - the percentage of households entirely without the use of a water closet - emerged as the most significant additional factor, contributing a further 8% to the overall explanation of the distribution. The mapped residuals in this case (figure 5.18.) revealed a dramatic contraction in the area occupied by significantly high residuals, particularly South Tyneside. On the other hand, the reduction in the area occupied by strong negative residuals was considerably less noticeable.

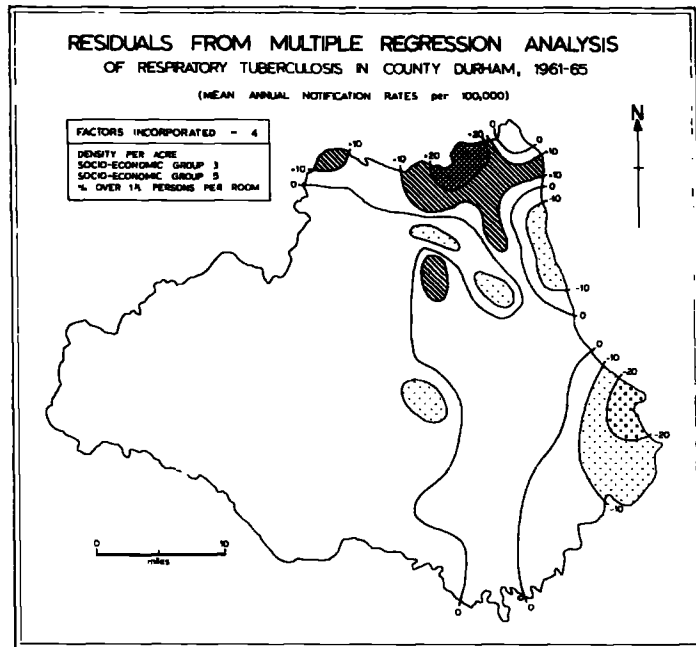


Figure 5.17.

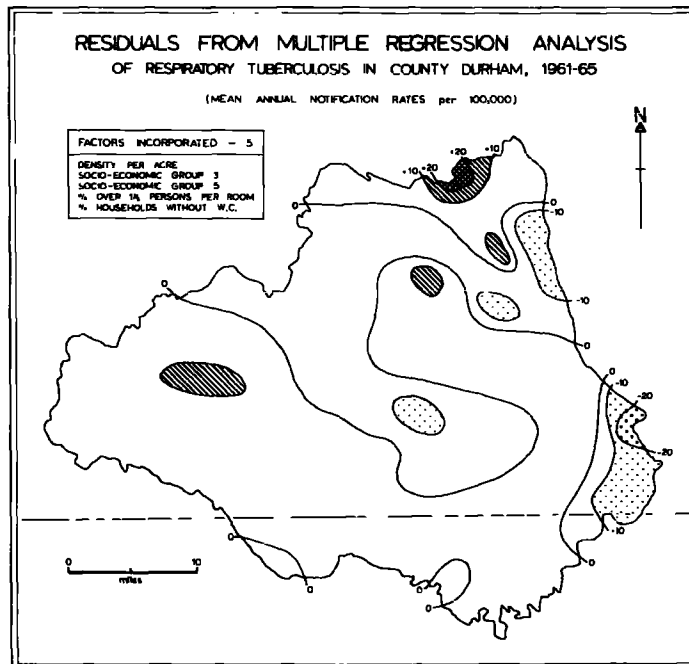


Figure 5.18.

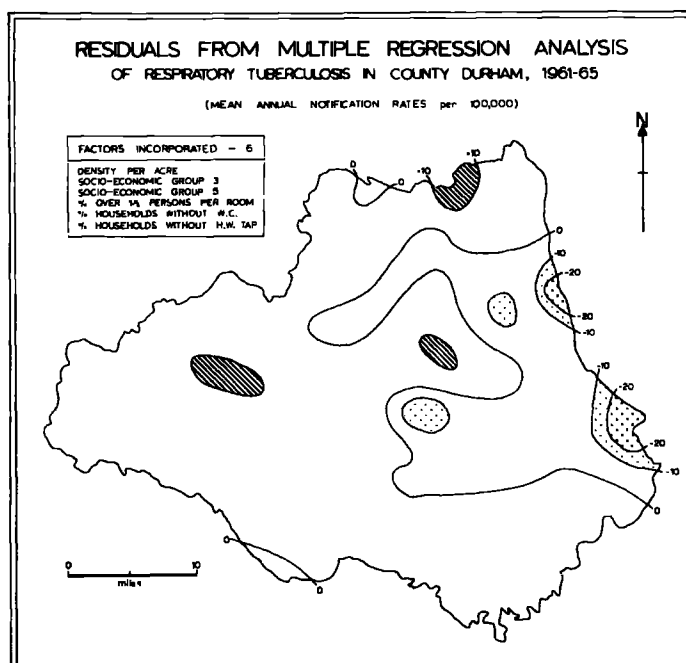


Figure 5.19.

By taking the process a stage further and incorporating a sixth factor (in addition to the five considered above), it was found possible to achieve a further reduction in the area of positive residuals in Tyneside, although it was noted that there was a compensatory increase in the negative residuals, particularly in the Seaham area (figure 5.19.). In this case, the most significant additional factor was found to be factor 12, the percentage of households sharing the use of a hot water tap. The coefficient of multiple correlation was 0.87, yielding 75% explanation of the overall distribution.

These results tended to suggest that at the local level the influence of certain factors related specifically to living conditions may indeed be considerably greater than had been originally suggested by the coefficients of simple correlation. In particular, the incidence of shared household facilities emerged as a distinct possibility. Under these circumstances, the hygienic standards maintained in respect of such facilities necessarily reflect the standards of the least sophisticated user of the group. Thus it may be seen that the health of the majority may eventually be jeopardised by the standards of a minority; a particularly relevant factor in the case of such an insidious disease as tuberculosis.

It is perhaps interesting to note that in the regression analysis involving six factors, the resultant regression coefficients were statistically significant for only four out of the six factors under consideration.⁽¹⁾ At this level, the influence of the two factors involving the percentage of the male population in socio-economic groups 3 and 5 respectively was substantially reduced. Indeed, the resultant regression coefficients relating to these two factors failed to demonstrate any

(1) viz:- Density per acre, the percentage of the population living at more than $1\frac{1}{2}$ persons per room, the percentage of households entirely without a water closet and the percentage of households sharing a hot water tap.

measure of statistical significance. This suggests that the considerable measure of statistical association between these factors and the incidence of respiratory tuberculosis, noted in the case of the coefficients of simple correlation, may well have reflected the indirect influence of other more significant elements of causation. Thus, it would appear that the more likely association between socio-economic status and tuberculosis may be found in the home environment rather than the place of work.

5.7. Discussion and conclusions

During the five-year period under consideration (1961-65) the notification rate for respiratory tuberculosis in County Durham declined by approximately 30%. Nevertheless, the County still continued to rank fifth amongst the counties of England and Wales in respect of its mean annual notification rate.

When the situation was analysed more closely, it was discovered that, as at the national level, the greatest reductions in morbidity rates were being recorded in the predominantly rural areas. In contrast, the urban areas and in particular the county boroughs were experiencing little or no improvement in this direction. Moreover, bearing in mind the fact that the urban areas had started the period at a distinct disadvantage in relation to the rural districts, this process was inevitably leading to a progressive accentuation of the existing disease foci, at least in relative terms. This was particularly so in the marked reservoir area of South Tyneside.

A simple correlation analysis of the relationship between the annual notification rates for respiratory tuberculosis and 21 selected indices of the social environment revealed a considerable number of statistically significant coefficients of correlation. Despite the fact that many of these statistical associations had been expected to occur

(by virtue of the evidence provided by previous workers in this field) the Durham situation nevertheless provided a number of interesting anomalies.

Of the 21 factors considered, density per acre yielded the strongest and most consistent statistical association with the notification rates for respiratory tuberculosis (table 5.6.). This tended to suggest that absolute propinquity of persons, as affecting the rate and intensity of contact between susceptible and infective cases, remained the most significant single element in the web of causation. Moreover, bearing in mind the considerable rural/urban gradient of notification rates mentioned above, the concept of a critical or threshold density as a prerequisite for the continued propagation of this type of infectious disease presented itself as a distinct possibility. However, when the situation was considered from a spatial point of view, it was discovered that the influence of the density per acre factor appeared to vary substantially over area. In what may be termed the main reservoir areas of the County, the degree of association between this factor and the prevalence of tuberculosis was particularly strong ($R = + 0.91$). On the other hand, in the case of the less affected areas, (i.e. to the south and east of the County) the relationship was far less pronounced ($R = + 0.70$) although still statistically significant. This observation once more demonstrated the considerable momentum or inertia of the disease which is capable of being generated and sustained by a suitably large reservoir or 'volume' of infection.

Although the individual coefficients of correlation between the incidence of respiratory tuberculosis and the indices of living densities (persons per room) were somewhat lower than in the case of the previous density factor, the results still retained a substantial measure of statistical significance, particularly in the case of the overcrowding

index.⁽¹⁾ Moreover, it was interesting to note that a marked 'threshold' emerged between the high positive coefficients of correlation in the case of the higher living density indices and the significant negative or inverse relationships noted for the lower living densities (figure 5.14.). These findings tended to indicate that particular factors in the home environment were exerting a significant influence on the propagation of the disease at the local level. Under these circumstances it is perhaps more appropriate to view the epidemiology of tuberculosis in terms of a stochastic model (Bartlett 1956 and 1960, and Bailey 1950, 1953 and 1957). In this way the community may be thought of, not as a homogeneous whole, but rather as the resultant effect of a number of distinct sub-groups. Contact between individuals of the same sub-group is deemed to be significantly greater than the corresponding contact between individuals of different sub-groups. In the case of tuberculosis, the most effective sub-group in this sense is undoubtedly the family unit, since a considerable period of sustained contact between susceptible and infective case is normally required to effect the successful transmission of the bacillus. Even so the importance of the extended sub-group must not be overlooked in facilitating the initial introduction of the disease into the sub-group proper. In this latter connection the role of the place of work and the necessity for a number of family units to share particular household facilities must be regarded as fundamental.

The precise role of socio-economic status on the overall patterns of tuberculosis morbidity proved somewhat more difficult to determine. In purely statistical terms, significant positive relationships were noted in the case of socio-economic groups 3 and 5 (skilled and unskilled manual workers respectively) while a rather surprising inverse relationship

(1) The percentage of the population living at more than $1\frac{1}{2}$ persons per room.

was noted in the case of group 4 (semi-skilled manual workers, see figure 5.10.).

It may be argued that the significant differential noted above is explicable in terms of the variation in the conditions of employment between the different socio-economic groups. In this connection, the heavy engineering and ship-building concerns, situated along the south bank of the Tyne and employing a relatively high percentage of skilled and unskilled manual workers, would appear to offer the most likely conditions for the transmission of the disease outside the home environment. The frequent combination of a suitably large labour force and a variety of adverse conditions in the working environment ensures that a sufficiently high frequency and intensity of contact between individuals is maintained. Under these circumstances, a single 'active' case could provide an 'effective' contact for a surprisingly large number of susceptibles; thereby increasing the probability of the continued propagation of the disease within the community at large. This hypothesis is further supported by additional evidence presented in chapter 6 below, which concerns itself with a more detailed investigation of the tuberculosis situation within South Tyneside. Each of the three local authorities studied recorded a substantial excess of male morbidity from respiratory tuberculosis at all ages over 20 years (figures 6.1. and 6.2.). It might well be argued that this considerable sex differential reflects the greater exposure to infection experienced by the bulk of the male population in the working environment.

On the other hand, the apparent association between socio-economic status and the prevalence of tuberculosis may not necessarily reflect a causal relationship between the two factors. Indeed it is quite likely that the variation in the two variables may represent similar yet independent responses to a third and more significant factor. In this

connection, it is conceivable to regard socio-economic status as no more than an additional index of urbanisation which is conveniently coincident with the rural-urban gradient noted in the general distribution of the disease.

Turning to a consideration of the influence of general living conditions upon the level of tuberculosis morbidity, a number of statistically significant correlations were obtained in the case of factors relating to the availability or absence of specific household facilities. Moreover, of the five 'additional' factors considered (section 5.6.1.4.) by far the most significant results were obtained in the case of the rate of slum clearance, which may be adopted as a general index of the prevalence of sub-standard housing in an area. In contrast, the relationship between the absolute age of property (factor 2, the percentage of dwellings built before 1900) and respiratory tuberculosis, although still positive, failed to achieve the same degree of statistical significance. This tends to suggest that the general condition of housing exerts a somewhat greater influence in the propagation of tuberculosis than mere age of dwelling (Stein, 1952; Bradbury, 1933).

Multiple correlation analysis of the available data, demonstrated the essential interdependence of the variables which had been introduced to explain the distributional pattern of respiratory tuberculosis. Adopting density per acre as the principal factor in a progressive 'compounding' process, a considerable duplication of information was discerned even after the addition of the second factor. Under these circumstances, the increment in the percentage explanation of the distribution was considerably less than might have been suggested by the simple coefficients of correlation.

The mapped residuals of the regression involving four factors revealed a substantial under-estimation of morbidity in the north-east

of the County, and a marked over-estimation in the case of the Hartlepool area to the south-east. The subsequent addition of a fifth and sixth factor to the regression (both of which were indices of general living conditions) led to a substantial contraction of the area occupied by high positive residuals. At the same time, it was noticed that whereas the two density factors in the regression maintained their level of statistical significance in the more advanced stages of factor compounding, the role of socio-economic status in the regression was usurped by indices related more specifically to household amenity and by implication the home environment.

From the above evidence it was concluded that whereas the broader patterns of tuberculosis morbidity could be satisfactorily explained in terms of size and relative propinquity of the susceptible population; at the local level, social differentials become increasingly more important. In particular, the relative quality of housing - expressed in terms of the availability of specific household facilities, and the rate of slum clearance - would seem to be the most likely contributory factor. In contrast, the role of purely occupational factors appears somewhat less well-defined, despite the degree of association suggested by the coefficients of simple correlation.

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Chapter 6Tuberculosis in Tyneside:a case study

The preceding discussion and analysis at the county level (chapter 5) supported the theory that there was indeed a strong causal relationship between particular elements of the social and economic environment and the prevalence of respiratory tuberculosis. In particular, the influence of poor housing conditions defined in terms of a variety of different, yet inter-related, criteria has been suggested as the most significant single factor in determining the overall pattern of the disease in County Durham. By undertaking an investigation of the incidence of respiratory tuberculosis in those areas exhibiting persistently high notification rates, it was hoped to discover whether or not this same hypothesis was valid at the local level.

Figures 5.6. and 5.8. had indicated that the area of South Tyneside could be distinguished as an area of particularly high incidence of tuberculosis. "The existing statistics appear to indicate that the area is one of the worst places in England as regards the prevalence of tuberculosis" (Bradbury, 1933:77). Moreover, it is interesting to note that despite a concerted effort to 'explain' the geographical distribution in terms of specific social and economic criteria, significant positive residuals in this area remained unresolved (figures 5.17. and 5.18.). For the above reasons, the three local authorities of Felling, Hebburn and Jarrow were selected as the basis of a more intensive study of the disease.

In each of the three local authorities, application was first made to the local medical officers of health for permission to refer to the

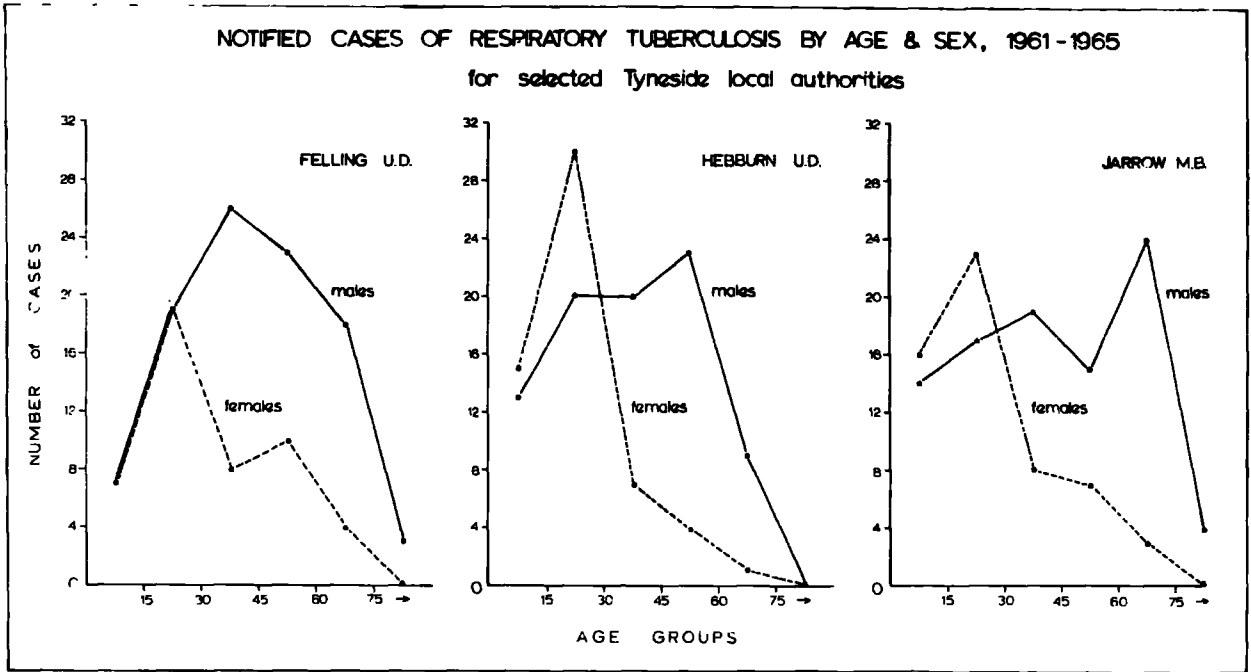


Figure 6.1.

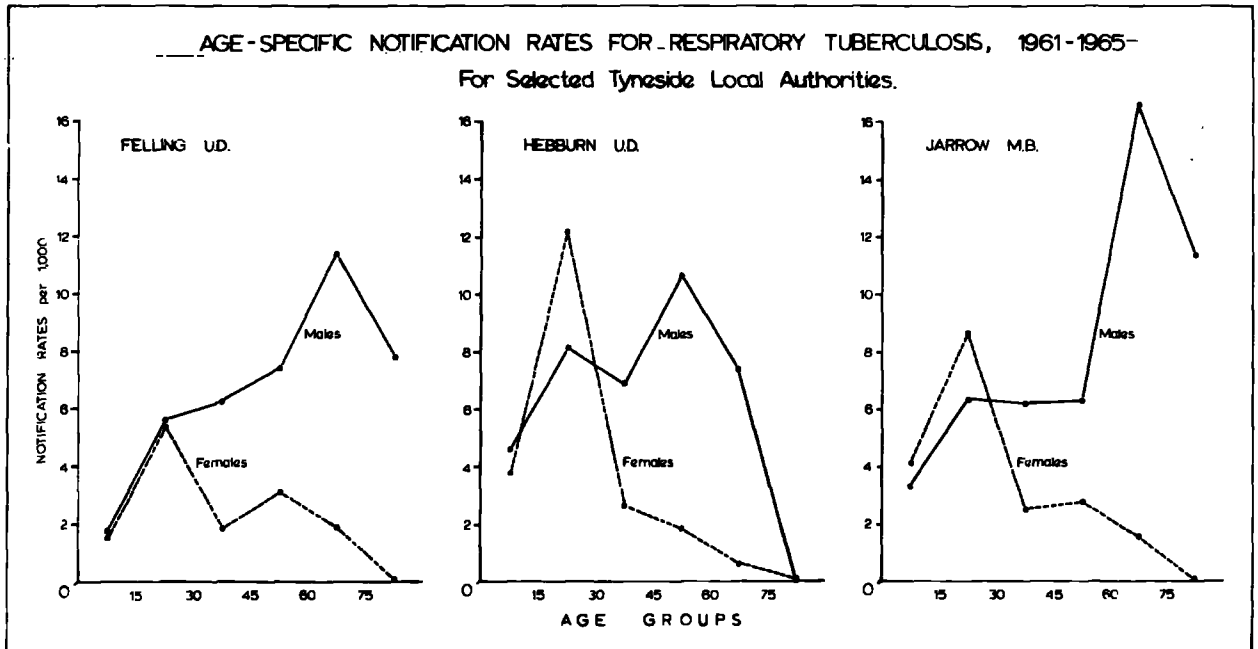


Figure 6.2.

relevant tuberculosis registers for the period 1961-5 inclusive. Details relating to the date of notification; the age, sex and address of the patient were then abstracted for each new case of the disease which was notified during the period. For Hebburn U.D. and Jarrow M.B. a statement of the occupation of individual patients was also obtained in most cases and tabulated accordingly.

The proportion of cases which were of the non-respiratory type was small (27 out of a total of 440 cases) and as a result the subsequent analysis is only concerned with those cases resulting from the respiratory form of the disease.

6.1. The age and sex distribution of cases

The age and sex distribution of new notified cases of respiratory tuberculosis in the three selected local authorities is shown in table 6.1., and this is represented in diagrammatic form in figures 6.1. and 6.2.

Perhaps the most striking aspect of these statistics is the substantial differential between the sexes in respect of age-specific notification rates. Whereas the regime for females is characterised in all three authorities by a marked peak in the age-group 15-30, the male peak is not reached until late middle-age - viz. the 60-75 age-group in the case of Felling and Jarrow, and the 45-60 age-group in Hebburn U.D. Only in the case of Hebburn was a secondary peak discernible in the earlier part of the male regime (15-30 age-group). In the case of females, a slight, though insignificant, increase in incidence was noted in the age-group 45-60 in the case of Felling and Jarrow (figure 6.2.).

A more sophisticated statistical analysis of the age and sex incidence of tuberculosis further substantiated the significance of the regimes already defined. For each of the three local authorities under consideration, the observed frequency of notifications in particular age-groups was compared with the corresponding frequency that would be expected

to occur if there was no inherent difference between age-groups in respect of the prevalence of the disease (table 6.2.).

For males, a significant deficiency of notifications was noted in the age-group under 15 years for both Hebburn and Jarrow. In the case of Felling, the high chi-square value (14.19, for 1 df.) indicated that the deficiency was particularly marked ($P < 0.001$). For the 60-75 age-group, the chi-square values for Felling and Jarrow represented a highly significant excess of notifications, over and above the expected frequency. Hebburn, on the other hand, exhibited a significant excess of cases in the 45-60 age range only. The observed frequencies in all the other age-group categories did not appear to deviate substantially from the regime of expected frequencies.

For females, the marked excess of notifications in the 15-30 year age-group was found to be highly significant in all three local authorities, particularly in the case of Hebburn, where the chi-square value was 28.90 ($P < 0.001$). At every other age-group, with the exception of a significant deficiency of cases in the 60-75 age range at Hebburn, the observed frequencies did not deviate significantly from the expected values calculated on the existing age-structures of the respective local authorities.

The above results are basically consistent with the findings of Jessop (1955:75) in Warwickshire that "whereas the peak of total incidence was in the female age-group 15-24, the peak of incidence of infection cases was in the male group 55-64." However, Bradbury's analysis (1933:98) of respiratory tuberculosis in Jarrow revealed a maximum incidence amongst males "in the 15-25 group, instead of the 45-65 group as in most other districts."

This dramatic sex-differential in respect of age-specific notification rates has been explained partly in terms of purely physiological factors in the case of the excess of cases in the 15-30 group for females,

Local Authority	Sex	Total	Age-group (yrs.)					
			-15	15-30	30-45	45-60	60-75	75+
FELLING U.D.	M	98	9	19	26	23	18	3
	F	50	9	19	8	10	4	0
HEBBURN U.D.	M	85	13	20	20	23	9	0
	F	57	15	30	7	4	1	0
JARROW M.B.	M	93	14	17	19	15	24	4
	F	57	16	23	8	7	3	0

Table 6.1. The distribution of cases of respiratory tuberculosis by age and sex for selected Tyneside local authorities, 1961-5.

	Age-group	population [*]	obs.freq.	exp.freq.	χ^2	probability	
FELLING U.D.	Males	0-15	5,395	9	29.5	14.19	p<0.001
		15-30	3,360	19	18.3	0.02	-
		30-45	4,155	26	22.7	0.49	-
		45-60	3,085	23	16.8	2.25	-
		60-75	1,578	18	8.6	10.24	0.01>p>0.001
		75+	384	3	2.1	0.39	-
	All ages	17,957	98	98	50.23	p<0.001	
	Females	0-15	5,140	9	14.0	1.76	-
		15-30	3,460	19	9.4	9.83	0.01>p>0.001
		30-45	4,068	8	11.0	0.83	-
		45-60	3,210	10	8.7	0.19	-
		60-75	2,014	4	5.5	0.39	-
		75+	527	0	1.4	1.43	-
All ages	18,419	50	50	14.43	0.05>p>0.01		
HEBBURN U.D.	Males	0-15	3,422	13	23.4	4.65	0.05>p>0.01
		15-30	2,494	20	17.1	0.49	-
		30-45	2,878	20	19.7	0.01	-
		45-60	2,166	23	14.8	4.48	0.05>p>0.01
		60-75	1,208	9	8.3	0.06	-
		75+	241	0	1.7	1.65	-
	All ages	12,409	85	85	11.33	0.05>p>0.01	
	Females	0-15	3,308	15	15.0	0.00	-
		15-30	2,474	30	11.6	28.90	p<0.001
		30-45	2,668	7	12.1	2.18	-
		45-60	2,085	4	9.4	3.18	-
		60-75	1,550	1	7.0	5.20	0.05>p>0.01
		75+	433	0	1.9	1.97	-
All ages	12,518	57	57	41.43	p<0.001		
JARROW M.B.	Males	0-15	4,120	14	27.2	6.41	0.05>p>0.01
		15-30	2,675	17	17.7	0.03	-
		30-45	3,091	19	20.4	0.09	-
		45-60	2,387	15	15.8	0.04	-
		60-75	1,450	24	9.6	21.71	p<0.001
		75+	354	4	2.3	1.18	-
	All ages	14,077	93	93	29.45	p<0.001	
	Females	0-15	3,908	16	15.1	0.05	-
		15-30	2,662	23	10.3	15.66	p<0.001
		30-45	3,090	8	12.0	1.31	-
		45-60	2,452	7	9.5	0.65	-
		60-75	1,950	3	7.5	2.73	-
		75+	672	0	2.6	2.59	-
All ages	14,734	57	57	22.99	p<0.001		

* The population figures used in this table were obtained from the Registrar General's census returns for 1961.

Table 6.2. A chi-square analysis of new notifications of respiratory tuberculosis by sex and age for selected local authorities in Tyneside, 1961-5.

	Total	Socio-economic Group					
		1	2	3	4	5	Unemployed
% of male working population	100	7.4	13.8	47.1	12.5	15.9	3.3
Observed number of notifications	85	3	8	35	15	21	3
Expected number of notifications	85	6.2	11.7	40.1	10.7	13.5	2.8
χ^2	9.3	1.6	1.2	0.6	1.7	4.2	0.0
Significance	-	-	-	-	-	0.05 > P > 0.01	-

Table 6.3. An analysis of primary notifications of respiratory tuberculosis in Hebburn U.D. and Jarrow M.B., 1961-65, by socio-economic status for males of working age.

and partly in terms of deleterious working conditions in the case of the male peak in the 60-75 age-group (Dahlberg 1949:224; see also Appendix B).

6.2. Occupational status of tuberculous patients

Although the occupational status of tuberculosis patients was generally recorded in both the local authorities of Hebburn and Jarrow, it was not possible to undertake more than a superficial study of the topic. This arose partly as a result of the available data being incomplete, and partly because the statement of occupation was not sufficient in every case to establish the exact socio-economic status of the patient. Nevertheless, a cursory examination of the available statistics did reveal some rather interesting results. Altogether 85 males of working age, whose occupation was stated, were tabulated for the five year period (table 6.3.).⁽¹⁾

When the observed frequency of notifications in each of the five socio-economic groups was compared with the expected frequency which might have been expected to occur if there was in fact no inherent difference between groups in this respect, the association of tuberculosis and particular occupational factors was highlighted. In particular, the evidence tended to suggest a continuous gradient from socio-economic group 1, with a perceptible though statistically insignificant deficit of notifications, to group 5 with a statistically significant excess of cases. These results accorded reasonably well with the findings of both Merrett (1959) and Benjamin (1953), although they tended to diverge somewhat from the situation for County Durham as a whole. In the latter

(1) The expected numbers of notifications in Table 6.3. were calculated on the basis of the employment structure of the two local authorities derived from the Registrar General's Census returns for 1961, Socio-economic tables (1966).

Each male patient of working age was assigned to the appropriate socio-economic class, on the basis of the information supplied in the tuberculosis register, and the classification of industry tables (Registrar General, 1966).

connection, it is interesting to note that the number of notifications amongst males in socio-economic group 3 (skilled manual) was less than might have been expected to occur under the null hypothesis. This tended to conflict with the evidence at the county level which suggested a strong positive correlation between the proportion of the population in socio-economic group 3 and the prevalence of tuberculosis. In addition, it was interesting to note that in the case of group 4 (semi-skilled manual) there was a marked although statistically insignificant excess of notifications. This again tended to conflict with experience at the county level, where a significant inverse relationship had been demonstrated (see figure 5.10., and also Merrett, 1959:160).

Such inconsistencies at the local level tended to suggest that, whereas particular indices of socio-economic status might prove useful criteria for the explanation of broad patterns of tuberculosis incidence, at the local level, they appeared to play a less significant role. Indeed, in the case of socio-economic groups 3 and 4 (skilled and semi-skilled manual workers) the observed relationships were apparently reversed.

6.3. Spatial distribution of notified cases

Having obtained the home addresses of all patients notified as tuberculous, it was possible to plot individual cases on the 6 inches to one mile base maps of the three local authorities. In most cases, it was not possible to assign individual notifications to their exact locations within a given street. Consequently in the majority of cases the 'best estimate' location was accepted and plotted accordingly. Notwithstanding this inherent limitation, the resultant distributions proved perfectly satisfactory for the purposes of subsequent analysis, since the greater part of the spatial investigation was concerned with the comparison of 'zones' rather than point foci.

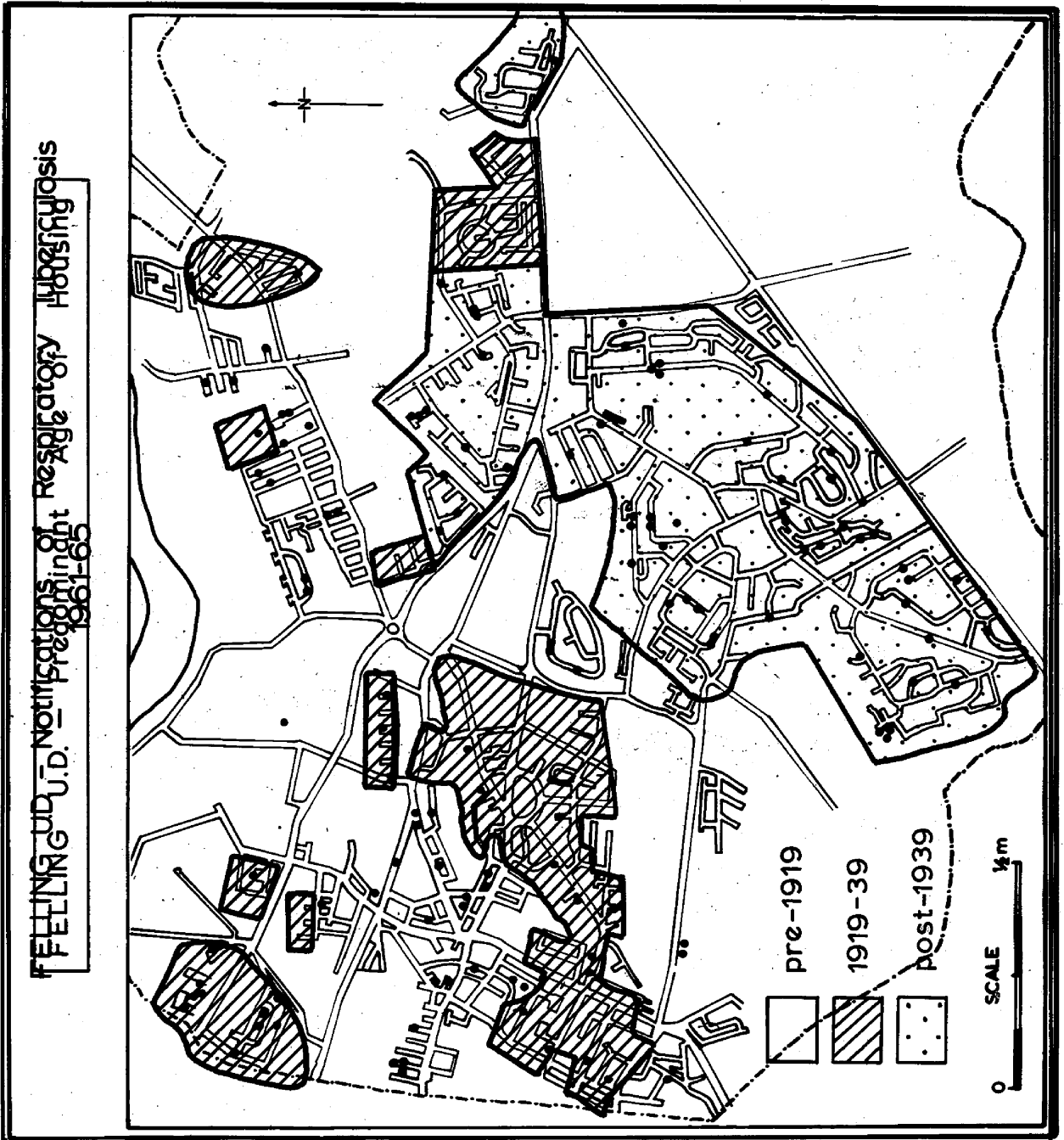


Figure 6.3.

Initially it was decided to compare and contrast the patterns of disease for individual years between 1961 and 1965, to discover whether or not the disease was migrating from one area to another through time. However, a cursory examination of the resultant maps, together with appropriate statistical tests, failed to reveal any significant variations between years in respect of the geographical distribution of cases. It was therefore decided to consolidate the data for the entire five year period and to consider only a single disease pattern for each of the three local authorities concerned (figs. 6.3., 6.4. and 6.5.).

Rather surprisingly, in none of the three maps was it possible to discern a marked concentration of notifications. However, locally a number of minor clusters of cases were apparent, although invariably these clusters were attributable to a single 'outbreak' within a tuberculous family. A notable exception to this was to be found in the north-east of Hebburn U.D., where a boarding house for working men recorded no less than seven cases of respiratory tuberculosis during the five year period.

6.3.1. The influence of housing on the spatial distribution of notifications in Jarrow M.B., Felling U.D. and Hebburn U.D., 1961-65

The findings of Stein (1952) and Bradbury (1933) tended to suggest that poor housing was an extremely significant factor influencing the perpetuation and the transmission of tuberculosis (see Appendix C). Moreover, the statistical analysis at the county level (chapter 5 *supra*) had tended to reinforce the validity of this hypothesis for County Durham as a whole.

For each of the three local authorities, a transparent overlay of 'predominant age of dwelling'⁽¹⁾ was prepared and superimposed upon the

(1) The information used in the preparation of the transparent overlays showing predominant age of dwellings was derived from the work of Kirby (1970) and Shoebridge (1969).

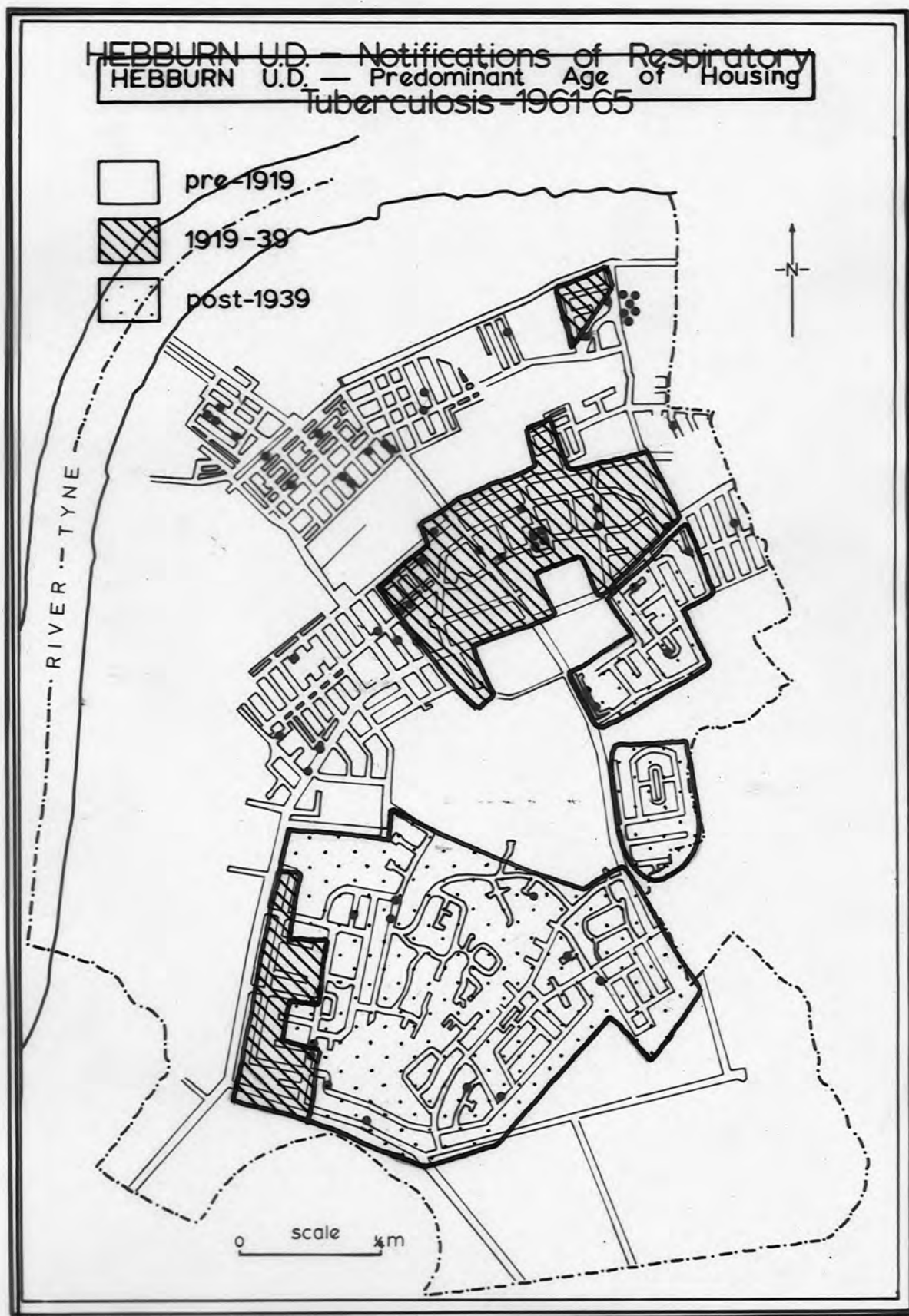


Figure 6.4.

corresponding map showing the geographical distribution of notifications from respiratory tuberculosis (figs. 6.3., 6.4 and 6.5.). By this means it was possible to obtain the number of notifications occurring in each of the three 'age of dwelling' categories which had been selected (viz. pre-1919, 1919-1939 and post 1946). By comparing these figures with the number of notifications which might have been expected to occur under the null hypothesis it was hoped to discover whether or not the age of housing was exerting a significant effect upon the overall distribution of tuberculosis at the local level. In particular, it was thought probable that the total lack or inadequacy of household amenities in the older type of dwelling would have been conducive to a marked concentration of cases in such areas.

For the purposes of this aspect of the investigation, two basic assumptions were made in order to undertake the necessary statistical comparisons. Firstly it was assumed that the three 'age of dwelling' categories contained on average approximately the same number of persons per dwelling unit in each case. Secondly it was assumed that the age of a dwelling in which a particular notified case occurred was in fact consistent with the 'predominant age of dwelling' as defined by the transparent overlays. In the latter case, it is quite reasonable to make this assumption in respect of all three local authorities, since successive phases of urban expansion have tended to occur in distinctive zones of housing estates, predominantly to the south of the old urban nucleus in each case (see the overlays for figs. 6.3., 6.4. and 6.5.).

Table 6.4. provides a summary of the results obtained from the subsequent analysis. In the case of Felling, the observed frequency of cases in the three categories corresponded almost exactly with the expected regime, calculated purely in terms of the resident population. A similar situation was apparent in the urban district of Hebburn, although in this

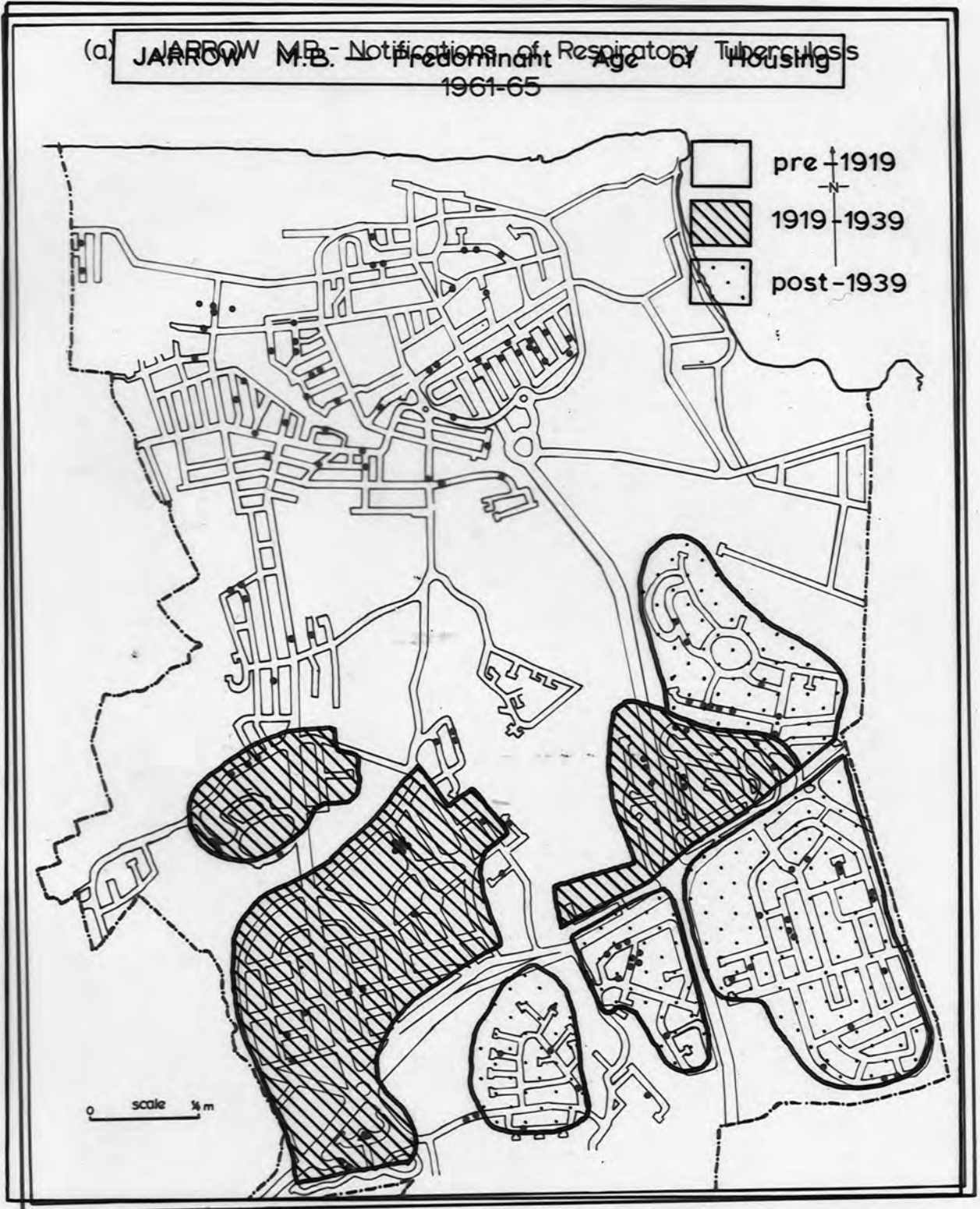


Figure 6.5.

Local Authority	'Predominant age of dwellings'			
	pre-1919	1919-39	post-1946	total
FELLING U.D.				
Number of dwellings*	3,755	3,210	5,486	12,451
Obs. No. of cases	41	33	59	133
Exp. No. of cases	41	34	58	133
χ^2	0	0	0	0
Significance	-	-	-	-
HEBBURN U.D.				
Number of dwellings*	3,352	2,119	2,750	8,221
Obs. No. of cases	32	16	19	67
Exp. No. of cases	27	17	23	67
χ^2	0.93	0.06	0.70	1.69
Significance	-	-	-	-
JARROW M.B.				
Number of dwellings*	4,358	2,292	1,772	8,422
Obs. No. of cases	67	33	43	143
Exp. No. of cases	75	39	29	143
χ^2	0.85	0.93	6.78	8.56
Significance	-	-	0.01 > P >0.001	0.01 > P >0.001

* Information obtained from the work of P. Shoebridge (1969) and D.A. Kirby (1970). The statistics refer to the situation in 1966.

Table 6.4. An analysis of the incidence of respiratory tuberculosis in three Tyneside local authorities in relation to the age of dwelling for which cases were notified.



PLATE 2. Nineteenth century terraced housing situated in the urban nucleus of Jarrow M.B. The houses shown in the photograph are of a far superior quality to those already demolished in connection with the numerous redevelopment schemes undertaken since 1950.

case there was a slight suggestion of an excess of notifications in the pre-1919 category. However, this difference could in no way be considered statistically significant.

In contrast, the results for Jarrow were considerably more significant, albeit unexpected. A highly significant ($0.01 > P > 0.001$) excess of notifications was noted in the case of the post-1946 category of dwelling. A corresponding, though less significant, deficit of cases was noted in both the pre-1919 and 1919-1939 dwelling categories.

6.4. Discussion and conclusions

The above results tended to suggest that at the local scale, the more significant areas of poor and inadequate dwellings - principally those in the pre-1919 age category, see Plate 2 - were not yielding a significant excess of tuberculosis notifications as might have been expected. Indeed, in the case of Jarrow, the areas of most modern housing (Plate 3) emerged as the most significant reservoirs of infection, despite their considerable superiority in respect of the provision of basic household amenities.

This somewhat anomalous situation may be explained largely in terms of the extensive programme of urban renewal which has been taking place in South Tyneside since the mid-fifties. For example, in Jarrow M.B. from 1955 onwards, on average 200 families were rehoused per annum. This meant that in the ten year period up to and including 1965, approximately one quarter of the borough's population was rehoused. ⁽¹⁾

Basically speaking, the process of urban renewal involved the demolition of the worst tracts of nineteenth century slum property adjacent to the main urban nuclei, and the removal of the displaced

(1) The information relating to urban renewal in Jarrow M.B. since the war was supplied by the head of the Housing Department in Jarrow.



PLATE 3. Dwellings built during the 1960's to the south of the urban nucleus in Jarrow to accommodate families displaced by urban renewal, mostly from areas of nineteenth century terraced housing.

population to modern housing estates located towards the south of each of the local authorities concerned. Since in the initial stages only the worst areas of slum property were removed, the pre-1919 dwellings that remained were on average of a relatively superior quality. As a result a situation emerged in which the residents of the worst slum areas, constituting the major reservoir of tuberculosis infection (as recognised by Bradbury (1933) in Jarrow), were removed to modern housing estates, while the better areas of pre-1919 dwellings, with proportionately fewer tuberculous families, remained relatively unchanged.

Inevitably the improvements in social environment experienced by the rehoused population must be expected to induce a substantial lowering of tuberculosis notifications in the future. This will result partly from the availability of all basic household amenities in the modern housing estates, and partly from a marked reduction in living densities. Both these processes will help to reduce both the frequency and the intensity of contact between the susceptible and the tubercle bacillus.

Nevertheless, the inherent momentum of the disease within the rehoused population will ensure that the elimination of the disease from this area of Tyneside will be a gradual rather than a sudden process, despite the rapid amelioration of living conditions within the area. From this it may be seen that slum clearance is not in itself a panacea as far as the prevention of tuberculosis is concerned. It must inevitably be supported by a comprehensive programme of education and vaccination of the population at risk by the local health authorities concerned.

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Chapter 7'Suspected Food Poisoning' Cases
in Consett Urban District, 1964-5.

"The Consett Iron Company which has already spent £1.5 millions on anti-pollution measures is to spend a further £170,000 to try and end the problem altogether.

Residents of Consett have complained that a red dust blown from the chimneys of the works causes houses, roads and cars to glow red, and is a danger to health."

Daily Telegraph Saturday,
11 July 1970, p. 3.

7.1. Introduction

This study of 'suspected food poisoning' was prompted by periodic references to the Registrar General's weekly returns of 'Births, Deaths, Infectious Diseases and Weather' during the course of the initial investigation of measles and tuberculosis in County Durham. It was discovered that during the initial 10 weeks of 1967 the Urban District of Consett (figure 7.1.) in County Durham was returning approximately 5% of all notifications of dysentery for England and Wales, and an only slightly lower percentage of notifications in the case of suspected food poisoning. Since the population of Consett U.D. at the 1961 census constituted no more than 0.08% of the total population of England and Wales, the high incidence of these two disease categories was deemed to warrant further investigation.

An interview with a representative of the Medical Officer of Health for Consett revealed that the high notification rates were in all

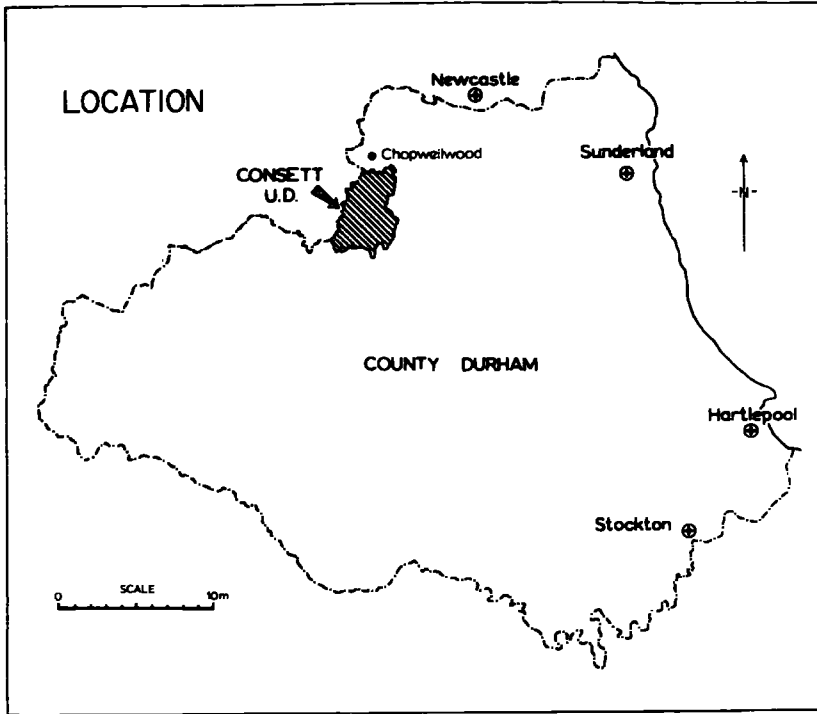


Figure 7.1.

NOTIFICATIONS OF 'SUSPECTED FOOD POISONING'
 IN ENGLAND AND WALES 1964-1965
 (By Standardised Four Week Months)

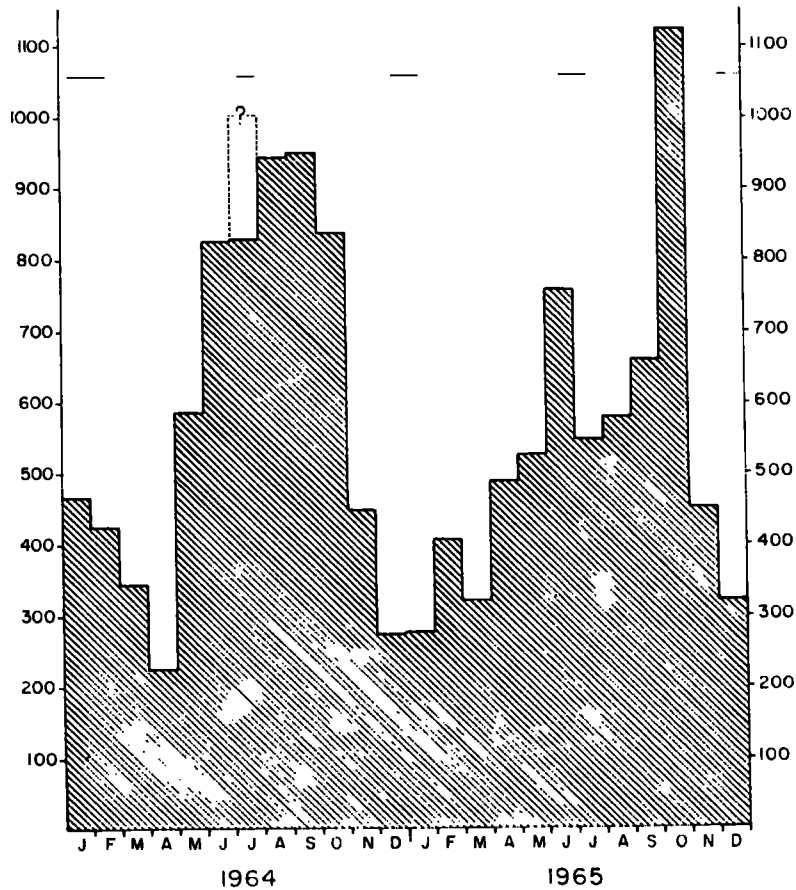


Figure 7.2.

probability not due to any inherent environmental factor peculiar to Consett itself. Rather it was suggested that the excess could be explained purely in terms of more rigorous notification of stomach and intestinal disorders in the local area. The opinion was expressed that in the case of more 'minor' notifiable diseases, including scarlet fever, measles and intestinal disorders, undernotification was accepted as an inevitability for the country as a whole. Quite apart from the many cases which are sub-clinical in nature, and are thus not brought to the attention of the authorities, many others may be deemed unworthy of notification by the general practitioner.⁽¹⁾ Moreover, as so often happens, there may be a considerable time lapse (3-7 days) between the original diagnosis of the disease and the actual notification of the case at the Local Council offices. This invariably means that the doctor has a much longer period of time to observe a particular case of disease. Should his original diagnosis prove to be inappropriate he may still be in a position to retract it before the actual process of notification has taken place.

The combined effect of the above factors will be to reduce considerably the overall number of notifications for particular disease categories. Ultimately one will be left with only the 'tip of the iceberg' from which to draw tentative conclusions.

In the case of Consett, however, it would appear that notification for both dysentery and suspected food poisoning is considerably more complete than for many other areas in England and Wales. This situation afforded a valuable opportunity to investigate the incidence of what may be termed 'other ill-defined stomach and intestinal disorders' which are

(1) A fee of 2/6 was payable by a local authority for each case of notifiable disease registered by a doctor. This amount is not in itself a sufficient inducement to ensure complete notification. (With effect from October 1968 the fee has been raised to 5/-).

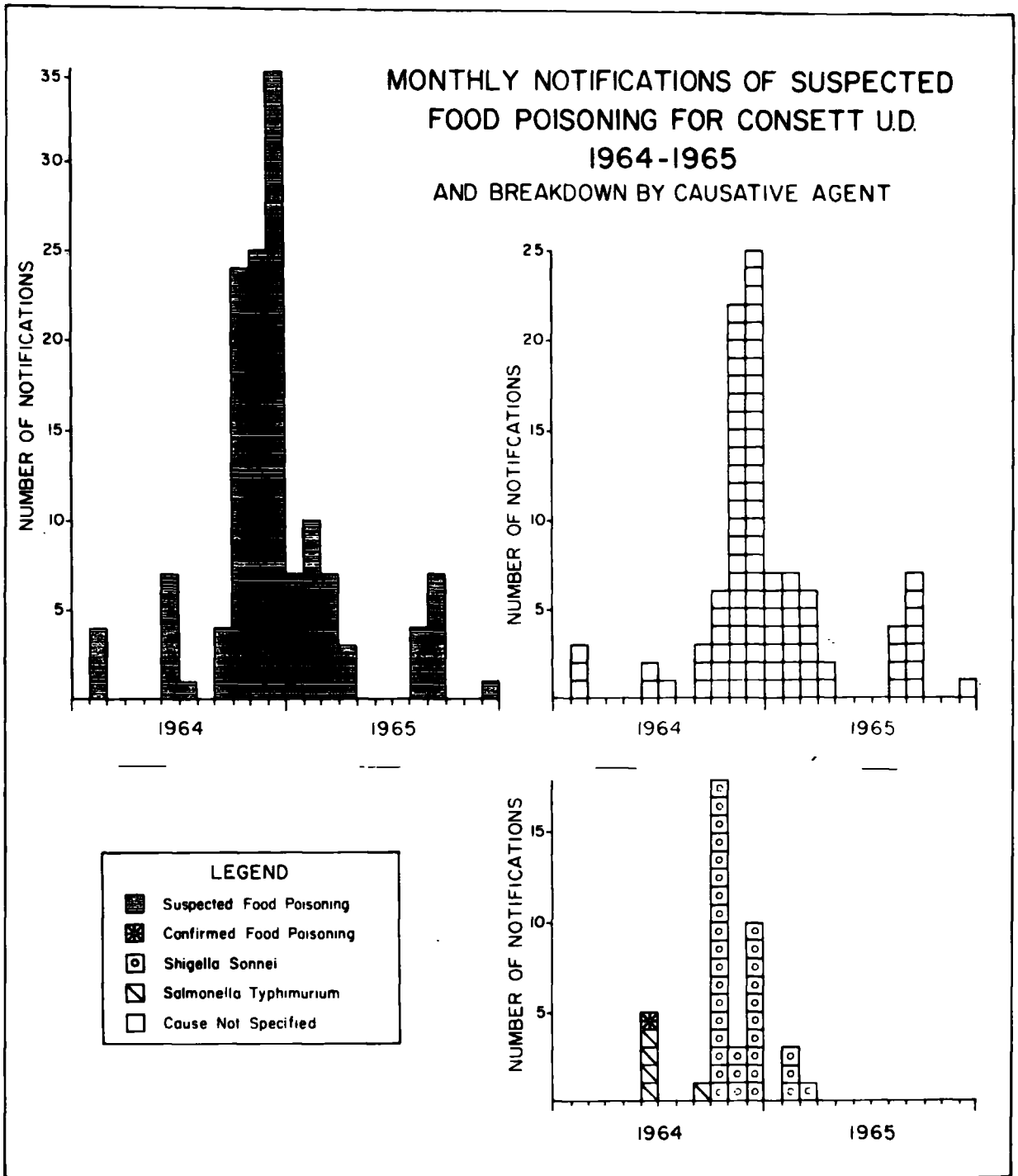


Figure 7.3.

not normally required to be notified.⁽¹⁾ In this connection Goldsmith (1964) has coined the phrase 'untoward symptoms' which he defines as "symptoms which in the absence of an obvious cause ... might lead a person to seek medical attention and relief." This type of disorder, noted above, may by its very nature be readily confused with either dysentery or food poisoning, at least in the initial diagnosis.

7.2. Data collection

A cursory examination of the Registrar General's weekly returns at the time of data collection - February 1967 - indicated that a considerable number of suspected food poisoning cases were notified for Consett U.D. during the winter of 1964-5. (Figure 7.3.) This appeared to be a particularly promising starting point for the investigation, and consequently the two-year period January 1964 to December 1965 was adopted as the initial time datum.

Application was then made to the medical officer of health at Consett, who kindly made available the infectious disease register for consultation and abstraction of statistics. For each case of 'suspected food poisoning' during the above period, the following details were abstracted and recorded on index cards:-

- a) Date of notification
- b) Home address of patient
- c) Sex
- d) Age
- e) Results of subsequent Laboratory analysis
- f) Occupation of the patient (available in only a limited number of cases).

(1) For the purpose of this paper it has been assumed that although no bacteriological agent may have been isolated in the laboratory following the initial diagnosis of 'suspected food poisoning', a substantive disorder is nevertheless deemed to exist in each notified case, which may or may not be due to some other causative element.

Unfortunately, in the case of dysentery, the records for the period were found to be incomplete, and, as a result, this part of the investigation had to be abandoned.

7.3. Preliminary analysis

7.3.1. Distribution of cases of 'suspected food poisoning'

7.3.1.1. Substantiated cause - During the period January 1964 to December 1965 a total of 137 cases of suspected food poisoning were notified in the Urban District of Consett. Of these, only a single case - a 2½ year old male - was actually confirmed as 'food poisoning' as a result of subsequent analysis. Thirty-six cases (26.3%) were attributed to Shigella Sonnei, and a further 5 cases (3.6%) to Salmonella Typhimurium.⁽¹⁾ The remaining 95 cases (69.3%) proved negative. That is to say, the causative agent was not specified (see Table 7.1.).

From the above it may be seen that during the period under study the notification of 'suspected food poisoning' at Consett bore little or no relation to the prevalence of food poisoning, per se. Rather it would appear that it was a substantially better measure of what may be termed 'other ill-defined intestinal and stomach disorders'.

7.3.1.2. Through time - Figure 7.3. shows how the cases of suspected food poisoning approximated to an 'epidemic' regime in the period 1964-5, exhibiting a marked peak in December 1964. Indeed, the three months of October, November and December accounted for no less than 84 (61%) of the total number of cases during the two year period. In addition, two other more minor periods of incidence occurred during June and July of 1964, and during August and September of the following year. However, these two minor episodes combined accounted for only 19 (13%) of the

(1) In all probability the 5 cases of Salmonella Typhimurium were also associated with actual food poisoning (Huckstep, 1962) but this fact was not specifically noted in the records.

Age	Number of notifications	Males	Females	Substantive cause			
				Food poisoning	Shigella Sonnei	Salmonella Typhimurium	Cause not specified
Under 5	45	21	24	1	9	2	33
5 - 9	24	13	11	-	10	1	3
10 - 19	19	6	13	-	6	1	2
20 - 39	29	17	12	-	6	-	23
Over 40	20	7	13	-	5	1	14
TOTAL	137	64	73	1	36	5	95

Table 7.1. The Distribution of all 'Suspected food poisoning' cases in Consett U.D., 1964-5, by age, cause and sex.

recorded cases.

When the incidence of the cases is analysed in respect of substantive cause, the overall distribution through time is found to reflect a compound of essentially different regimes (figure 7.3.). The single confirmed food poisoning case, together with the five cases of salmonella typhimurium, occurred prior to the main periods of incidence - viz. in the summer and early autumn of 1964. In contrast, the 36 shigella Sonnei cases occurred during the period October 1964 and March 1965. Individual peaks in October and December suggested two distinct waves of infection.⁽¹⁾

The numerically significant residue - 'ill defined stomach and intestinal disorders' - occurred predominantly during the winter months at the end of 1964. The months of November and December were particularly dominant; accounting for approximately 50% of all the cases in this category.

Whilst the seasonal distribution of Sonne dysentery cases in Consett for the period concur favourably with the findings of Bradley et al. (1958) - i.e. that it is "a disease of the colder rather than the warmer months of the year", the situation in respect of all suspected food poisoning cases for Consett U.D. appears to diverge quite significantly from regime recorded for England and Wales as a whole. Figure 7.2., constructed from the weekly returns of the Registrar General (1965-6), indicates the existence of marked summer and autumn peaks during the period 1964-5. However, it is interesting to note that the month of minimum incidence over the country as a whole (December 1964) coincided with the peak month for Consett in particular (figure 7.3.). Consett's contribution of 32 cases of suspected food poisoning to the December total

(1) This latter hypothesis was given added weight by the spatial analysis of cases, which revealed an October 1964 outbreak of dysentery in the north of Consett (in the Medomsley ward) and a more localised outbreak in the south (ward of Consett South) in the December of the same year.

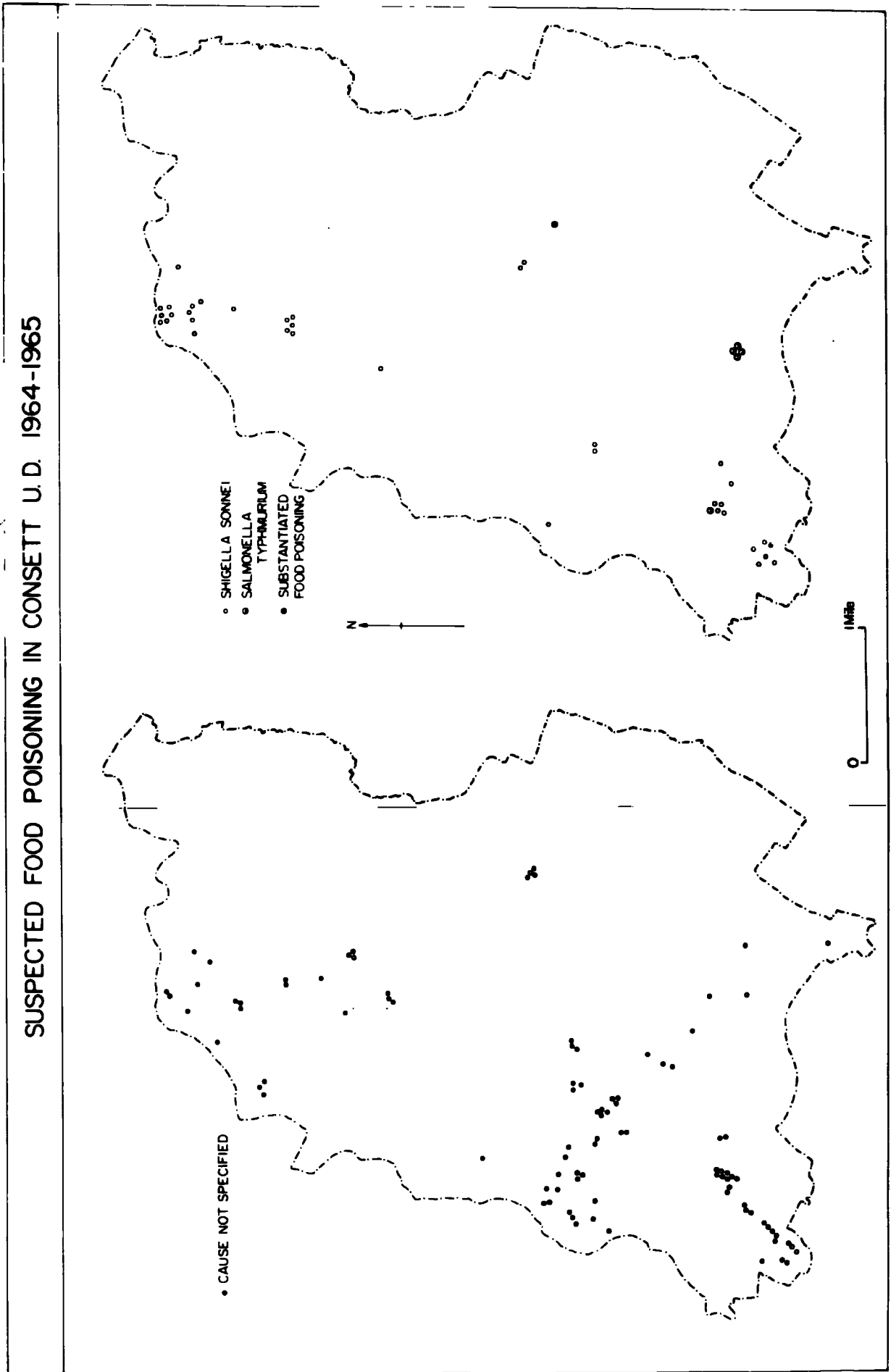


Figure 7.4.

for 1964 represented over 11% of the overall national incidence. This considerable discordance in regime noted above tended to suggest the presence of particular environmental influences at Consett, which were essentially localised in their effect.

7.3.1.3. Age and sex - An analysis of the cases by age revealed that approximately 50% of all cases of suspected food poisoning occurred under the age of ten years. When considered by cause, a similar proportion (50% of cases under the age of ten) was found to exist in the case of both *Shigella Sonnei* and other 'ill-defined stomach disorders'. (cf. Bradley et al., 1958).

A chi-square test⁽¹⁾ of the age and sex distribution of 'all suspected food poisoning' cases revealed that there was not a significant difference between the sexes in respect of incidence other than that which could be explained in terms of accidents and errors of sampling.

7.3.1.4. Occupation - In only 10 of the 137 notified cases was the occupation of the patient recorded, and it was therefore not possible to pursue this particular avenue of research further.

7.3.2. The spatial distribution of cases

Each case of suspected food poisoning (1964-5) was plotted on to an outline map of Consett U.D. (figure 7.4.) using the home address of the patient, and a six inch to one mile Ordnance Survey map of the area. Precise location in every case was impossible, since the numerical order of houses in particular streets could not be ascertained from the mere cartographic evidence. Nevertheless, the approximate assignments of individual cases were sufficiently accurate, at this scale, to permit the construction of two distribution maps (figure 7.4.) which appeared

(1) A statistical test which is used to measure the divergence of an observed distribution from an expected distribution.

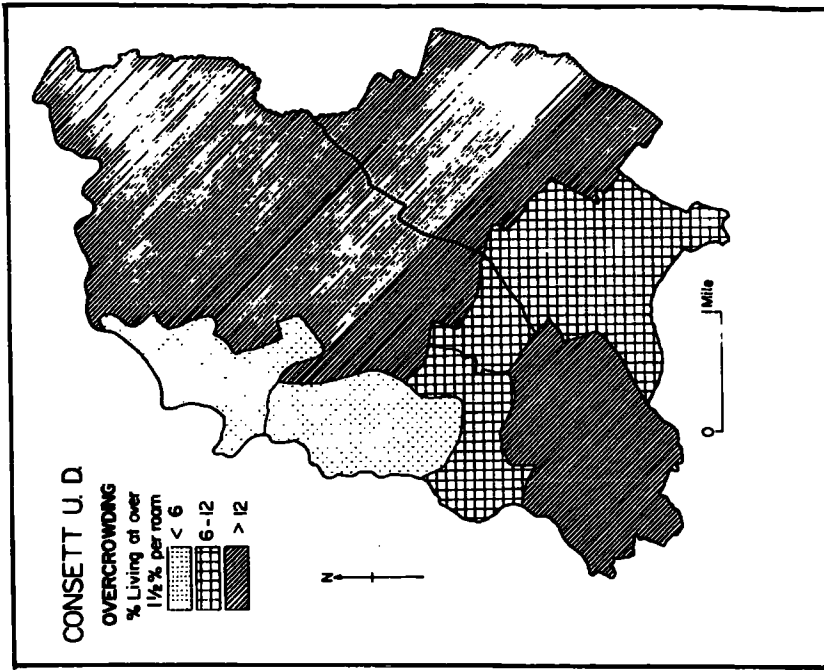


Figure 7.7.

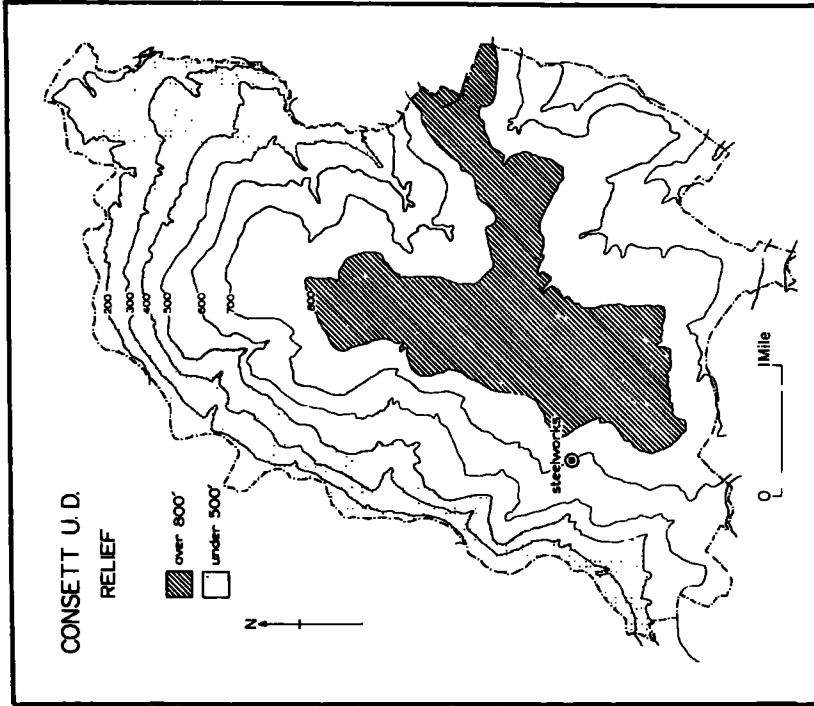


Figure 7.6.

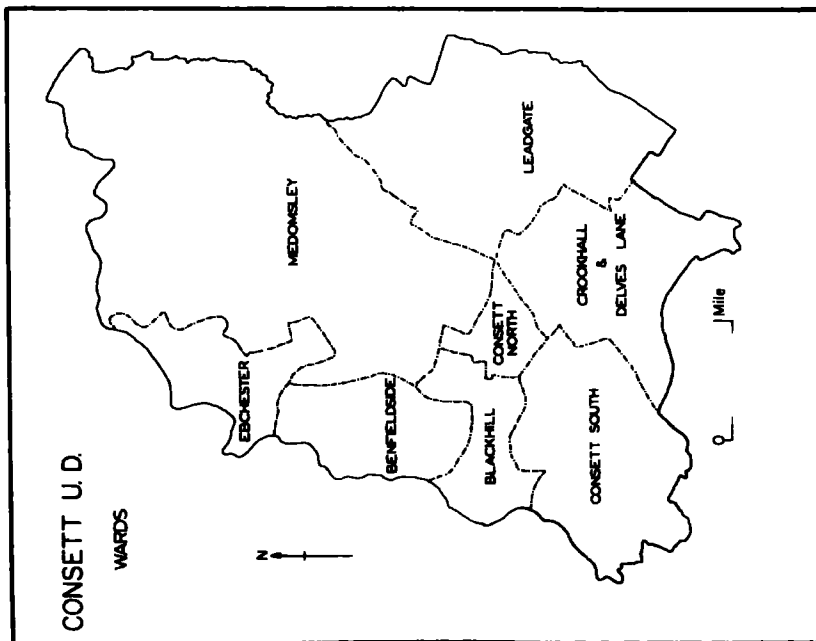


Figure 7.5.

to reflect significant patterns of disease.

In particular, the general clustering of Sonnei dysentery in the north of the urban district (Medomsley Ward) and to a lesser extent in the Grove Estate area of Consett South Ward was quite marked. On the other hand, the distribution of the single confirmed food poisoning case, and the five cases of salmonella typhimurium, must inevitably be considered no more than an expression of random occurrence, by virtue of the small numbers involved. Indeed, since four of the five salmonella typhimurium cases represented a localised family outbreak, the significance of the scatter is even further reduced.

In contrast, the spatial distribution of the negative cases - the 'ill defined stomach disorders' - appeared particularly significant (figure 7.4.). The two major clusters of incidence were located in the south-west of the district (Consett South Ward) and in the ward of Blackhill immediately to the north (figure 7.5.). Indeed, of the 95 cases in this category, 58 (61%) were located within the boundaries of these two wards, with a combined population of 12,477, or only 32% of the total population of the urban district.

More rigorous analyses of the data were then undertaken to ascertain the statistical significance of the above spatial distributions.

Initially a chi-square test was made on all 'suspected food poisoning' cases, whereby the observed incidence by ward was compared with the expected ward incidence assuming no inherent difference between wards (Table 7.2.).⁽¹⁾ In particular, the wards of Medomsley, Blackhill and Consett South displayed a highly significant excess of cases, with chi square values in excess of 9 ($0.01 > P$). In contrast, Benfieldside, with an observed frequency of only 1 case, showed a very highly significant deficit of cases. The wards of Consett North, Crookhall and Delves Lane,

(1) The expected values were obtained by allocating the total number of cases (137) between the wards, in proportion to their total populations.

Ward	Population (1961)	Frequency observed	Frequency expected	χ^2	Probability
Benfieldside	5,722	1	20.07	18.12	$P < 0.001$, $df = 1$
Blackhill	5,295	33	18.57	11.21	$P < 0.001$, $df = 1$
Consett North	3,772	4	13.20	6.41	$0.02 > P > 0.01$, $df = 1$
Consett South	7,182	41	25.20	9.91	$0.01 > P > 0.001$, $df = 1$
Crookhall & Delves Lane	5,174	9	18.14	4.60	$0.05 > P > 0.02$, $df = 1$
Ebchester	1,342	5	4.66	0.02	Not significant
Leadgate	4,677	7	16.39	5.33	$0.05 > P > 0.02$, $df = 1$
Medomsley	5,780	37	20.77	12.68	$P < 0.001$, $df = 1$
TOTAL	38,944	137	137	68.28	$P < 0.001$, $df = 7$

Table 7.2. A geographical analysis of all 'suspected food poisoning' cases in Consett U.D., 1964-5, by ward.

Ward	Population	Frequency observed	Frequency expected	χ^2	Probability
Benfieldside & Ebchester*	7,064	5	17.23	8.68	$0.01 > P > 0.001$, $df = 1$
Blackhill	5,295	30	12.92	22.58	$P < 0.001$, $df = 1$
Consett North	3,772	4	9.19	2.931	Not significant
Consett South	7,182	28	17.52	6.27	$0.02 > P > 0.01$, $df = 1$
Crookhall & Delves Lane	5,174	5	12.62	4.60	$0.05 > P > 0.02$, $df = 1$
Leadgate	4,677	4	11.41	4.81	$0.05 > P > 0.02$, $df = 1$
Medomsley	5,780	19	14.11	1.69	Not significant
TOTAL	38,944	95	95	51.56	$P < 0.001$, $df = 6$

* In the case of the ward of Ebchester, the expected frequency fell below 5 and it was therefore decided, for statistical purposes, to combine Ebchester with the adjacent ward of Benfieldside.

Table 7.3. A geographical analysis of 'negative' (cause not specified) cases of suspected food poisoning in Consett U.D., 1964-5, by ward.

and Leadgate were also significantly below their expected frequencies.

A second chi square test was then made on the 'negative' cases only, in order to eliminate the effects of the substantive cases and in particular those due to shigella Sonne.

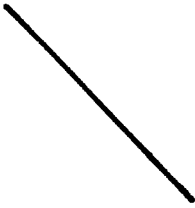
Under these circumstances (Table 7.3.) Medomsley ward no longer exhibited a significant excess of notifications. It may be therefore concluded that it was in all probability the clustering of the Sonne dysentery cases in the ward which had elicited the significant excess of cases noted in the previous test (Table 7.2.). On the other hand, the wards of Consett South and especially Blackhill still displayed significantly higher levels of incidence than might have been expected, despite the small sample size. All the remaining wards continued to show a significantly lower number of cases than would have been expected under the null hypothesis.

This substantial and statistically significant divergence of the geographical distribution of suspected food poisoning cases from a random scatter contributed even further to the hypothesis that specific environmental influences were active in promoting these spatial differentials.

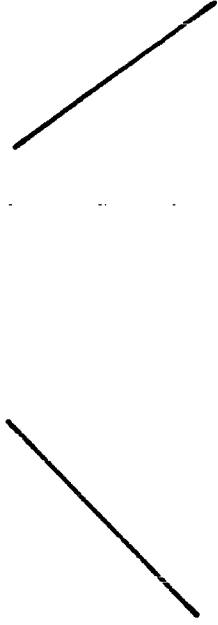
7.4. Aetiological factors

In the case of the 36 Sonne dysentery cases, the distribution map (figure 7.4.) reveals that all but six of the cases occurred in the wards of Medomsley and Consett South. Of the remaining thirty cases, eighteen occurred in the former, and twelve in the latter ward. This surprising predominance in both Medomsley and Consett South probably reflects differentials in the social environment between wards. In this respect, the preponderance of old or inferior types of housing may often indicate a relatively low proportion of living space per person. This invariably means an increase in overcrowding, which in its turn has a marked effect upon the sanitary arrangements and thereby the hygienic standards of a

Iron & Steelworks



Housing Estates



River Derwent



Consett from the west

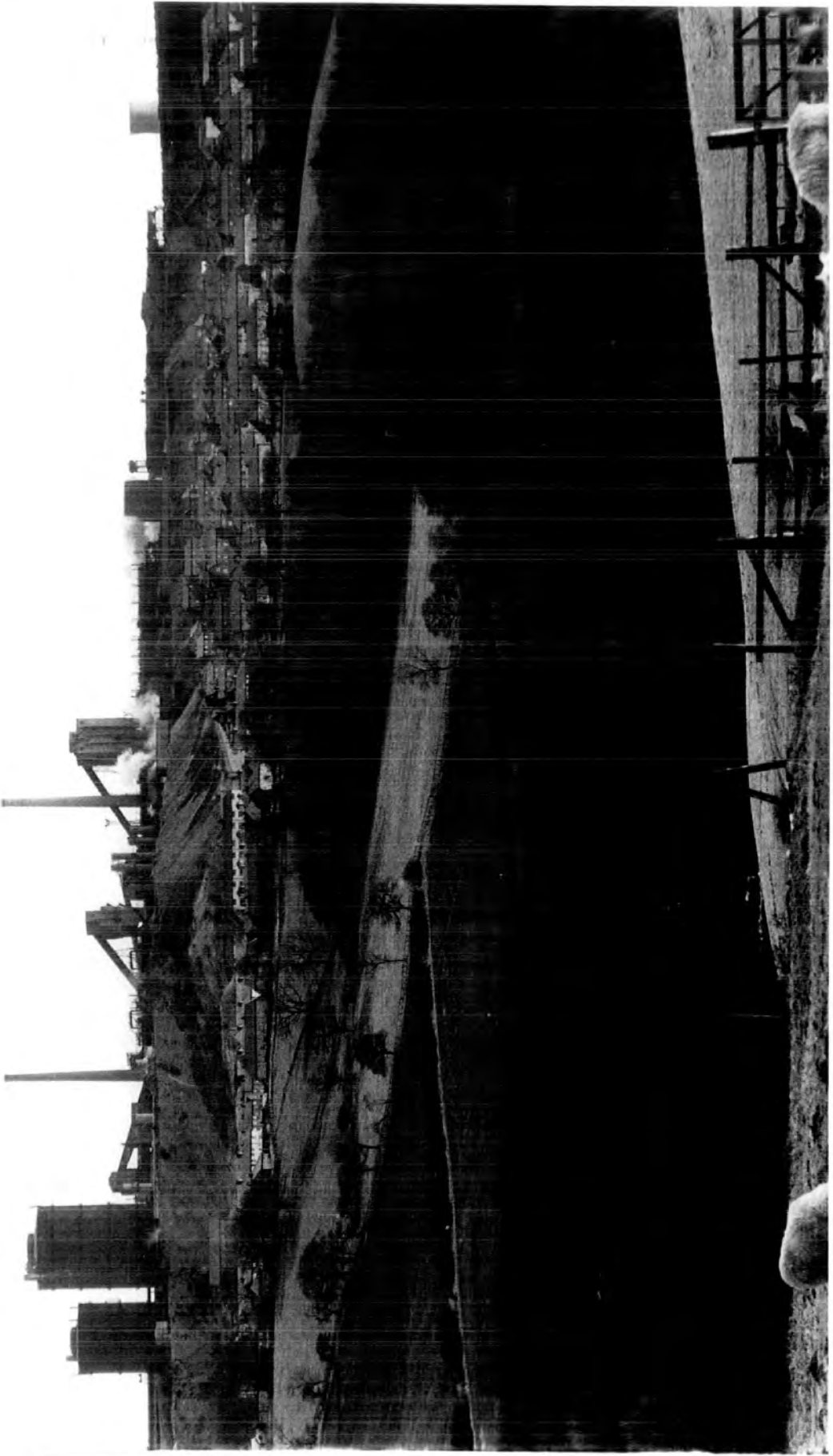


PLATE 4*

particular district. In this connection, it is interesting to note from the map of overcrowding (figure 7.7.) - i.e. the percentage of the population living at more than $1\frac{1}{2}$ persons per room - that both Medomsley and Consett South have significantly high rates of overcrowding, viz. 14.9% and 12.9% respectively (General Register Office, 1963). This compares with a figure of only 4% for the ward of Benfieldside and 9.7% for County Durham as a whole. However, bearing in mind the small sample size, it is impossible to draw more than tentative conclusions from these results. Nevertheless, the available evidence does appear to be compatible with the findings of Taylor (1956) that "The distribution of high dysentery incidence did ... appear to have some relationship to at least one of the environmental indices, namely the average number of persons per room."

The distribution of the 95 'negative' cases of suspected food poisoning, exhibiting a marked clustering in the south-west of the Urban District, almost certainly indicated a significant deviation from a random scatter (figure 7.4.). In particular, it was noted how the clustering of cases was especially marked in the vicinity of the large iron and steel works (Plate 4). Moreover, by comparing the distribution of the 'negative' cases (figure 7.4.) and the relief (figure 7.6.) it may be seen that the bulk of the cases in this area occurred below the physical level of the works itself - that is, below 700'. This contrasts sharply with the ward of Consett North, which, although at the same distance from the works as the other two wards, experienced a significant deficit of cases. However, in this case the ward was situated at a higher elevation than the iron works - i.e. around 800'.

From the above evidence it was postulated that the cause of the marked inflation in the incidence of ill-defined stomach disorders at Consett was related in some way to the large iron and steel works in the

south-west of the Urban District. Air pollution, and in particular iron ore dust, was deemed to be the most likely causative agent. It is further postulated that if a specific concentration of particulate matter (iron ore dust) were ingested over a suitable time, it could well act as a sufficiently strong stomach irritant to elicit a variety of symptoms, including diarrhoea, abdominal pain and nausea. This would obviate the need for any bacteriological explanation. Moreover, under these circumstances, the whole effect would tend to become even more pronounced during the winter months, when prolonged periods of high atmospheric pressure would produce marked inversions of temperature. This latter situation would inevitably mean that a considerable quantity of the pollutants (including the iron dust) would become trapped in the rather restricted valley of the River Derwent to the west of the works.

In the case of iron ore dust per se, it proved impossible to obtain reliable data for the period under consideration. However, statistical information with respect to general air pollution was available for three different sites within the urban district of Consett (Warren Spring Laboratories, 1965 and 1966). Detailed statistics were obtained, on a monthly basis, for the following measures of pollution (in ppm) (a) mean smoke concentration (b) highest smoke concentration (c) mean sulphur dioxide concentration (d) highest sulphur dioxide concentration and (e) the ratio between the mean smoke and mean sulphur dioxide concentrations. These five parameters were then correlated with the monthly notifications of a) all suspected food poisoning cases and b) the 'negative' (cause not specified) cases only, for the main period of incidence - June 1964 to May 1965. The results are presented in Table 7.4.

Despite the small numbers of notifications involved, the coefficients of correlation were consistently high in specific cases. The positive coefficients which were found to exist between smoke pollution and the

	Recording site	Av. smoke concentration	Highest smoke concentration	Av. SO ₂ concentration	Highest SO ₂ concentration	Ratio smoke/SO ₂
All Cases of Suspected Food Poisoning	A	+0.78**	+0.77**	-0.14	+0.28	+0.81**
	B	+0.75**	+0.67*	-0.23	-0.44	+0.69*
	C	+0.79**	+0.80**	+0.02	+0.11	+0.71*
Negative Cases Only	A	+0.68*	+0.67*	-0.24	+0.17	+0.78**
	B	+0.62*	+0.53	-0.15	-0.37	+0.52
	C	+0.69*	+0.69*	+0.02	+0.10	+0.58

** 0.01 > P > 0.001 Highly significant

* 0.05 > P > 0.01 Significant

Site A - Consett South

Site B - Blackhill

Site C - Leadgate

Table 7.4. Coefficients of correlation between air pollution and cases of suspected food poisoning in Consett U.D., June 1964-April 1965.

total number of notifications were particularly significant ($P < 0.01$) for each of the three sites. However, it was noticed that when the 'negative' cases were considered on their own, the levels of significance somewhat diminished, though this could simply be explained in terms of reduced sample size. In contrast, none of the twelve coefficients obtained by correlating sulphur dioxide pollution with suspected food poisoning were found to approach statistical significance.

In an effort to substantiate further the validity of the suggested association between air pollution (smoke) and suspected food poisoning, it was decided to correlate additional meteorological parameters with the monthly notification of suspected food poisoning. It was hoped that, by doing so, it would be possible to demonstrate that the apparent association between air pollution and suspected food poisoning was in fact more than a mere reflection of other environmental factors underlying the regime of atmospheric pollution itself. For this purpose, the monthly statistics for Chopwellwood (situated immediately to the north of Consett Urban District - National Grid Reference 45/136530) were abstracted for the period June 1964 - April 1965. The coefficients of correlation which were subsequently computed are presented in Table 7.5. As may be seen, only four of the eight coefficients were statistically significant. Indeed, all the levels of significance were substantially lower than in the case of smoke pollution (see Table 7.4.).

As a further independent check, the same meteorological variables for Chopwellwood were correlated with the five indices of atmospheric pollution for one of the three recording sites in Consett (Table 7.6.). These results clearly demonstrate the inverse relationship between air temperature and specific measures of atmospheric pollution, notably smoke (Hutchinson, 1966). Indeed, each of the six coefficients of correlation between, on the one hand, the three temperature parameters, and

Meteorological variables (Monthly values)	All suspected cases of food poisoning	Negative cases only
Mean diurnal temperature	-0.66*	-0.60
Mean maximum temperature	-0.67*	-0.61*
Mean minimum temperature	-0.63*	-0.58
Total rainfall	-0.17	-0.25

* Significant ($0.05 > P > 0.01$)

Table 7.5. Coefficients of correlation between selected meteorological factors for Chopwellwood, and the notification of suspected food poisoning in Consett U.D., June 1964-April 1965.

Air pollution variables	METEOROLOGICAL VARIABLES (Monthly values)				Total rainfall inches
	Mean diurnal temperature (°C)	Mean maximum temperature (°C)	Mean minimum temperature (°C)		
Av. smoke concentration	-0.94***	-0.95***	-0.92***	-0.09	
Highest smoke concentration	-0.90***	-0.92***	-0.85***	-0.01	
Av. SO ₂ concentration	-0.39	-0.32	-0.47	+0.40	
Highest SO ₂ concentration	-0.35	-0.35	-0.35	+0.31	
Ratio: Smoke/SO ₂	-0.77**	-0.80**	-0.72*	-0.29	

*** Very highly significant ($P < 0.001$)

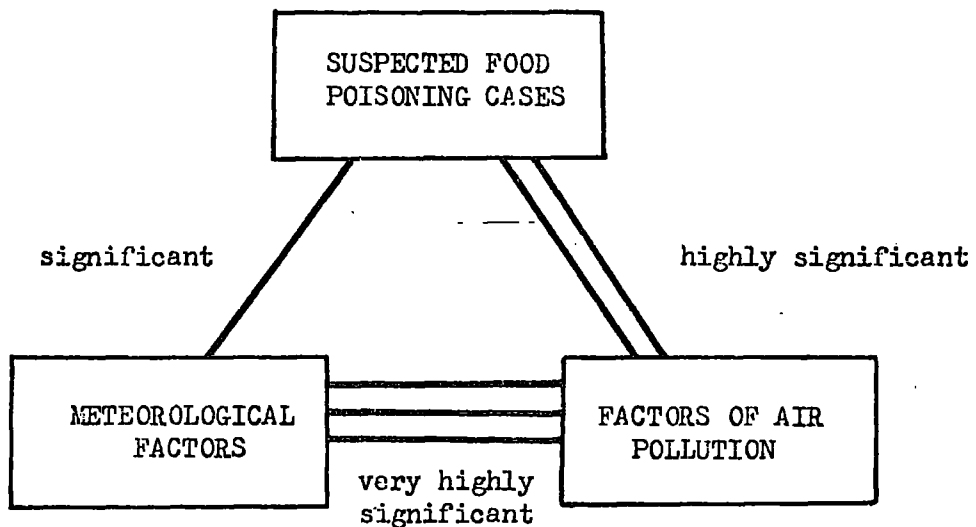
** Highly significant ($0.01 > P > 0.001$)

* Significant ($0.05 > P > 0.01$)

Table 7.6. Coefficients of correlation between selected meteorological variables for Chopwellwood and air pollution indices for recording site A (Consett South), June 1964-April 1965.

on the other the average smoke and highest smoke concentrations, were statistically speaking very highly significant ($P < 0.001$).

From the above evidence, it appeared that although the regime of atmospheric pollution (and in particular smoke pollution) was itself largely conditioned by particular meteorological factors (of which temperature was perhaps the most significant⁽¹⁾) it was the former which exerted the most significant influence on the incidence of suspected food poisoning in the Consett area during the period of study. This particular situation may perhaps be best illustrated by the following schematic diagram, in which the number of interconnecting 'struts' represents the degree of statistical association between individual groups of factors.



7.5. Conclusion

An examination of the Registrar General's weekly returns revealed that the incidence of suspected food poisoning cases for Consett U.D. appeared somewhat anomalous in respect of (a) the overall intensity of

(1) In the case of the regime of average smoke concentration, during the period June 1964-April 1965, over 90% of the total variation could be explained in terms of a single meteorological parameter (viz:- mean diurnal temperature).

occurrence and (b) the seasonal regime of notifications as compared with England and Wales as a whole. Although these peculiarities could be explained purely in terms of such factors as relatively over-zealous notification on the part of the general practitioners at Consett, the highly significant spatial clustering of cases, and the apparent relationship between the monthly incidence of cases and particular indices of air pollution, tended to suggest the interaction of specific environmental factors. In this connection, particulate material (including iron ore dust) derived from the extensive ore dumps and spoil heaps of the large iron and steel works at Consett was deemed a particularly important causative agent, especially in the case of the 'negative' cases, where a bacteriological cause was not specified. The location of the major clusters of cases below the level of the steel works, in the adjacent wards of Consett South and Blackhill (Plate 4), tend to support this basic hypothesis. Moreover, the coefficients of correlation obtained by correlating monthly incidence of suspected food poisoning with five different indices of air pollution, seemed to emphasise the significance of particulate pollutants as against those of a chemical nature.

Until now, the significance of atmospheric pollution in medical studies has been confined essentially to the realms of respiratory disease, and its associated effects on cardiovascular degeneration. The literature in this field is more than copious, and appears to be growing at an ever-increasing rate. By contrast, little attention has been paid to the possibility of there being more obscure associations between atmospheric pollution and disease. Indeed, despite the wealth of material which was readily available, it was only possible to discover one reference which suggested a possible causal relationship between air pollution and disorders of the digestive tract (Winkelstein and Kantor,

1969).⁽¹⁾ In a comparable environmental situation, Symon (1964) reports "frequent cases of anaemia amongst children between the ages of 7 and 12 years in one small industrial town with great dustfall from iron works and cement plants in a place where temperature inversions are common." But no mention is made of any marked surfeit of dysentery or similar symptoms.

It may be that since the majority of dysenteric symptoms are clinically mild, they are not to be considered so important as the chronic diseases such as bronchitis and tuberculosis. This may well be true; but it does not mean to say that this group of symptoms should be automatically discarded from further consideration. Indeed, bearing in mind the clinical mildness of the disease, the 137 cases of suspected food poisoning (and particularly the 95 'negative' cases) which were notified in Consett Urban District during the two-year period of study, could well have represented a far greater number of similar cases which were not in fact notified at all. In this connection Peters (1910) reports that, "only 8% of attacked persons over two years of age were found to apply to a doctor". Despite the fact that this statement referred to an age before the 'free' national health services, it helps to underline the fact that the problem of the 'negative' cases of food poisoning at Consett may well be many times in excess of the number of actual notifications. As such, it may be deemed to represent a considerable social and economic problem; not only in terms of working days lost, but also in terms of the cost of the expensive medical attention involved together with the associated laboratory charges for analysing faecal samples.

However, not until the community at large begins to realise that

(1) Dr. Newsholme (1899) in his treatise on Epidemic Diarrhoea does go so far as to state that the "disease is due to a particulate poison which infects the air, and is swallowed, most commonly with food, especially milk."

such relationships, like the one postulated in this study, do exist in reality, will effective steps be taken to reduce the incidence of this type of morbidity through the introduction of more rigid environmental controls. In this connection, Lawther (1964) points out that "today in a highly sophisticated industrial society, much has been done to prevent and abate air pollution and we are now asked hard questions concerning the price we are willing to pay to deal with the hard core of pollution, which is technically difficult to abolish. In place of mere strong feelings we must have hard facts concerning the effects of pollution in order to answer these questions."

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SECTION III

MORTALITY

"Mortality represents the end result of reaction to environment."

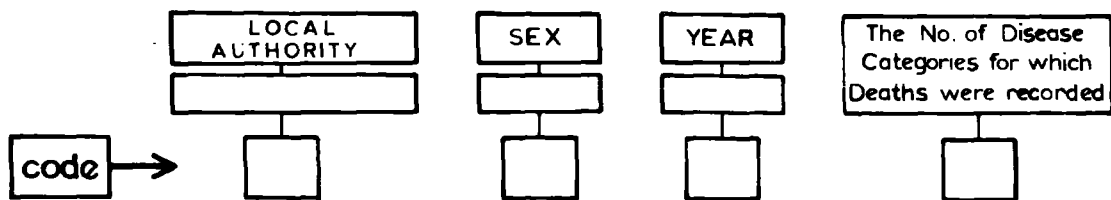
E.L. Collis (1925)

Chapter 8Mortality Data: Statistical Considerations8.1. Introduction

Individual deaths are notified in the first instance to the local registry office for births, deaths and marriages by either a general practitioner or hospital authority. The circumstances surrounding the death are entered on to appropriate cards which are subsequently despatched to a) the General Register Offices in London and b) the Chief Medical Officer of Health for the county or county borough concerned. The principal cause of death - that is to say the cause of death to which a particular death is primarily assigned for statistical purposes - is evaluated by the General Register Office (G.R.O.) from the medical evidence supplied by the doctor issuing the certificate of death. In particular cases where it proves impossible to derive the principal cause of death from the available evidence, the G.R.O. reserves the right to refer back to the doctor concerned in order to obtain additional information relating to the circumstances of death.

When the substantive cause of death has been established, the information is duly collated and stored by computer. In due course, summary data sheets, showing the annual mortality for each local authority in the country are produced from the data bank. Each sheet, which refers to a single local authority, provides a comprehensive tabulation of deaths by a) sex, b) age-group (12 categories) and c) principal cause of death (36 main causes). Copies of these tabulations are circulated to the respective local authority and County Medical Officers of Health for reference purposes. It is perhaps interesting to note that these

MORTALITY IN COUNTY DURHAM — 1963-67



cause of death	age-group-											
	ALL AGES	Under 1 yr	1-4	5-14	15-24	25-24	35-44	45-54	55-64	65-74	over 75	
RESPIRATORY TUBERCULOSIS	1											
TUBERCULOSIS, OTHER	2											
SYPHILITIC DISEASE	3											
DIPHTHERIA	4											
WHOOPING COUGH	5											
MENINGOCOCCAL INFECT.	6											
POLIOMYELITIS	7											
MEASLES	8											
OTHER INFECT. DIS.	9											
STOMACH CANCER	10											
LUNG CANCER	11											
BREAST CANCER	12											
CANCER OF UTERUS	13											
ALL OTHER CANCERS	14											
LEUKAEMIA	15											
DIABETES	16											
VASCULAR LESIONS	17											
CORONARY DISEASE	18											
HYPERTENSION	19											
OTHER HEART DISEASE	20											
OTHER CIRCULATORY DIS.	21											
INFLUENZA	22											
PNEUMONIA	23											
BRONCHITIS	24											
OTHER RESPIRATORY DIS.	25											
ULCER OF STOMACH	26											
GASTRITIS	27											
NEPHRITIS	28											
HYPERPLASIA	29											
CHILDBIRTH	30											
CONGENITAL MALFORM.	31											
OTHER ILL DEFINED DIS.	32											
MOTOR ACCIDENTS	33											
ALL OTHER ACCIDENTS	34											
SUICIDE	35											
HOMICIDE	36											
DEATHS FROM ALL CAUSES	37											

Figure 8.1.

tables, which are compiled by a somewhat remote agency in London, are nevertheless regarded as the official record of mortality at the county and local authority level. This is despite the fact that on numerous occasions local records may in fact show considerable discrepancies, particularly in respect of cause of death. Should these discrepancies prove excessive, the local medical officer is obliged to refer back to the G.R.O. in London in an effort to resolve the more striking of these anomalies.

8.2. Data collection and initial processing

For the purposes of the present study, application was made to the County Medical Officer for permission to abstract mortality statistics for the thirty-five local authorities within the administrative county of Durham, for the period 1963-67 inclusive. Similar approaches were also made to the appropriate authorities in the five county boroughs of Darlington, Gateshead, South Shields, Sunderland and West Hartlepool. In each case the statistics were derived from the annual summary sheets compiled and circulated by the Ministry of Health in London. An appropriate coding sheet was devised for the purpose (figure 8.1.), allowing for the convenient transfer of the data on to punched cards at a later stage. It should be noted that during the process of data abstraction, age categories 'under 4 weeks' and '4 weeks to 1 year' were rationalised to a single age group 'under 1 year'.

The initial transcription of the data on to the coding sheets proved somewhat laborious, since the process had to be repeated for both sexes over a period of five years and for each of the 40 local authorities. In all, a period of two weeks was spent in the preparation of the 400 data sheets, which were then submitted to the punch room of the university computer unit for transfer to punch cards.

A separate deck of cards was produced for each of the coding sheets - i.e. deaths recorded for a particular sex in a single local authority during one calendar year. The arrangement of a typical deck of cards is shown in figure 8.2.. The individual card decks were subsequently compounded into conveniently sized batches and subjected to an 'error' programme which was specially designed by the writer to detect and pinpoint basic copying and punching errors which had been introduced into the data bank during the two distinct phases of transcription outlined above. Basically speaking, the programme checked (a) that individual digits were punched in the correct columns on each computer card, (b) that the number of deaths recorded by individual age-group categories corresponded with the total for 'all ages' given in the second column of each card, and (c) that the total number of deaths recorded by cause for a particular age category corresponded with the respective total deaths 'from all causes' registered in the summary card for each deck (i.e. card 17 in figure 8.2.). All errors which emerged were duly resolved and the appropriate punch cards were replaced or suitably amended. The corrected deck was then resubmitted and subjected to the 'error' programme for a second time, to ensure that all the appropriate amendments had in fact been made, and that the deck was error-free.

When all the individual decks of cards had been duly checked and rechecked, they were arranged into a logical sequence (as indicated below) and subsequently stored on a magnetic tape with the aid of a further computer programme which was specially designed for the purpose.

DARLINGTON C.B.

Male Mortality

1963	.....	deck 1.
1964	.....	deck 2.
1965	.....	deck 3.
1966	.....	deck 4.
1967	.....	deck 5.

Female Mortality

1963	.....	deck 6.
1964	.....	deck 7.
1965	.....	deck 8.
1966	.....	deck 9.
1967	.....	deck 10.

GATESHEAD C.B.

Male Mortality

1963	.....	deck 11.
		etc., etc.

In this state, the total data bank was readily accessible, and indeed any single data item could be suitably located, abstracted and utilised in computation in a matter of a few seconds or even micro-seconds.

8.3. The standardisation of mortality data

In the study of mortality, the composition of the population at risk plays a considerable part in determining the rate at which individuals die, and also the proportion of deaths attributable to particular causes. Although the age- and sex-structure of the population is undoubtedly the most significant consideration in this connection (Daw, 1961; Conrad, 1962; Valaoras, 1956) a host of other demographic parameters such as socio-economic status (Hamilton, 1955; Logan, 1954; Kilpatrick, 1963; Sutherland, 1947) educational status (Upchurch, 1962)

SUNDERLAND C.B.

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1963 - MALE

CAUSE OF DEATH	TOTAL	UNDER 1	1-4	5-14	15-24	25-34	35-44	45-54	55-64	65-74	OVER 75
TUBERCULOSIS OF RESP. SYST.	13	0	0	0	0	0	1	2	4	4	2
SYPHILITIC DISEASES	2	0	0	0	0	0	1	0	1	0	0
MEMINGOCOCCAL INFECTION	2	1	1	0	0	0	0	0	0	0	0
OTHER INFECTIVE DISEASES	1	0	0	0	0	1	0	0	0	0	0
MALIG. NEOPLASM - STOMACH	52	0	0	0	0	0	0	4	14	27	10
MALIG. NEOPLASM - LUNG	83	0	0	0	0	0	1	8	35	32	7
ALL OTHER MALIG. NEOPLASMS	81	0	0	0	2	2	0	5	23	21	28
LEUKAEMIA AND ALEUKAEMIA	4	0	1	1	0	0	0	1	0	1	0
DIABETES	9	0	0	0	0	0	1	0	1	1	0
VASCULAR LESIONS OF C.N.S.	111	0	0	0	0	1	4	7	22	27	48
CORONARY DISEASE, ANGINA	249	0	0	0	0	1	8	24	76	60	74
HYPERTENSION OF HEART	10	0	0	0	0	0	0	0	2	4	4
ALL OTHER HEART DISEASES	51	0	0	0	0	0	4	2	6	11	28
OTHER CIRCULATORY DISEASES	27	0	0	0	0	0	1	3	4	7	12
INFLUENZA	9	0	0	0	0	0	0	3	1	2	3
PNEUMONIA AND BRONCH-PNEUM.	128	11	0	0	0	1	0	4	10	41	61
BRONCHITIS	124	0	0	0	0	0	3	7	39	39	36
OTHER DISEASES OF RESP.SYST.	12	0	0	0	0	0	0	1	6	2	3
ULCER OF STOMACH & DUODENUM	11	0	0	0	0	0	0	1	4	2	4
GASTRITIS,ENTERITIS,DIARRHOEA	4	0	0	0	0	0	1	1	0	2	0
NEPHRITIS AND NEPHROSIS	8	0	0	0	0	2	2	1	1	1	1
HYPERPLASIA OF PROSTATE	5	0	0	0	0	0	0	0	0	2	3
CONGENITAL MALFORMATIONS	14	12	0	1	2	0	0	1	0	0	0
ALL OTHER CAUSES OF DEATH	75	35	2	2	1	0	2	3	7	0	14
MOTOR VEHICLE ACCIDENTS	14	0	2	2	1	1	2	4	1	0	1
ALL OTHER ACCIDENTS	28	0	2	3	1	3	3	3	3	0	7
SUICIDE	17	0	0	0	1	3	2	4	4	2	1
HOMICIDE,OPERATIONS OF WAR	1	0	0	0	1	0	0	0	0	0	0
TOTAL OF ALL DISEASES	1147	59	8	9	9	15	36	91	264	303	353

ABSOLUTE NUMBER OF DEATHS RECORDED

CAUSE OF DEATH	TOTAL	UNDER 1	1-4	5-14	15-24	25-34	35-44	45-54	55-64	65-74	OVER 75
RESPIRATORY DISORDERS	24	18	0	0	0	6	11	18	22	27	27
INFECTIVE DISORDERS	0	1	12	0	0	6	2	0	0	0	0
CIRCULATORY DISORDERS	39	0	0	0	0	13	47	37	41	38	47
MALIGNANT NEOPLASMS	19	0	12	11	22	13	2	21	27	25	12
VIOLENT DEATHS	5	0	50	55	44	46	19	12	3	1	2
OTHER ILLNESSES	11	79	25	33	33	13	16	7	4	5	7

PERCENTAGE OF DEATHS BY CATEGORY

SUNDERLAND C.B.

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1963 - MALE

CAUSE OF DEATH	TOTAL	UNDER 1	1-4	5-14	15-24	25-34	35-44	45-54	55-64	65-74	OVER 75
TUBERCULOSIS OF RESP. SYST.	14	0	0	0	0	0	8	17	44	78	85
SYPHILITIC DISEASES	2	0	0	0	0	0	8	0	11	0	0
MEMINGOCOCCAL INFECTION	2	52	13	0	0	0	0	0	0	0	0
OTHER INFECTIVE DISEASES	1	0	0	0	0	7	0	0	0	0	0
MALIG. NEOPLASM - STOMACH	56	0	0	0	0	0	0	53	154	432	426
MALIG. NEOPLASM - LUNG	90	0	0	0	0	0	8	71	386	628	278
ALL OTHER MALIG. NEOPLASMS	88	0	0	0	16	15	0	44	254	412	174
LEUKAEMIA AND ALEUKAEMIA	4	0	13	5	0	0	0	8	0	19	0
DIABETES	9	0	0	0	0	0	8	0	11	19	255
VASCULAR LESIONS OF C.N.S.	121	0	0	0	0	7	32	67	243	567	2947
CORONARY DISEASE, ANGINA	271	0	0	0	0	7	64	213	840	1296	3150
HYPERTENSION OF HEART	10	0	0	0	0	0	0	0	22	78	170
ALL OTHER HEART DISEASES	55	0	0	0	0	0	32	17	66	216	1174
OTHER CIRCULATORY DISEASES	29	0	0	0	0	0	8	26	44	137	511
INFLUENZA	9	0	0	0	0	0	0	26	11	39	127
PNEUMONIA AND BRONCH-PNEUM.	139	574	0	0	0	7	0	35	110	805	2602
BRONCHITIS	135	0	0	0	0	0	24	62	431	766	1535
OTHER DISEASES OF RESP.SYST.	13	0	0	0	0	0	0	8	66	39	177
ULCER OF STOMACH & DUODENUM	12	0	0	0	0	0	0	8	44	39	170
GASTRITIS,ENTERITIS,DIARRHOEA	4	0	0	0	0	0	8	8	0	39	0
NEPHRITIS AND NEPHROSIS	8	0	0	0	0	15	16	8	11	19	42
HYPERPLASIA OF PROSTATE	5	0	0	0	0	0	0	0	0	37	177
CONGENITAL MALFORMATIONS	17	626	0	5	16	0	0	8	0	0	0
ALL OTHER CAUSES OF DEATH	81	1826	26	11	8	0	16	26	77	170	597
MOTOR VEHICLE ACCIDENTS	15	0	26	11	8	7	16	35	11	0	42
ALL OTHER ACCIDENTS	30	0	26	17	8	23	24	26	33	58	278
SUICIDE	18	0	0	0	8	23	16	35	44	39	42
HOMICIDE,OPERATIONS OF WAR	1	0	0	0	8	0	0	0	0	0	0
TOTAL OF ALL DISEASES	1251	3079	106	53	72	115	291	810	2919	5952	15059

AGE-SPECIFIC MORTALITY RATES PER 100,000

POPULATION BY AGE-GROUPS	91647	1916	7532	16791	12430	12932	17336	11232	9044	5070	2344
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Figure 8.3.

and race (Krueger, 1963) may be regarded as important contributory influences. For this reason, some form of initial standardisation of the raw mortality data is essential if subsequent spatial comparison is contemplated. In theory, the standardisation process seeks to eliminate, or at least to minimise, the effects of particular known sources of variation - notably age and sex.

The most basic form of standardisation is the crude mortality rate, expressed as the number of deaths per unit of population. This measure is almost exclusively employed at the national or international scale as a rough guide to the overall mortality situation. Used in conjunction with the crude birth rate and the infant mortality rate (expressed as the number of deaths under the age of one year per 1,000 live births) it can provide a useful indication of the relative stage of economic development of a particular country. However, at the local scale the crude mortality rate has little or no intrinsic value, particularly in the context of spatial comparison.

At the outset of the study, it had been hoped that by selecting a county with a population in excess of one and a half millions, and by considering a five year period, a suitably large 'quantum' of mortality would have been embraced to permit the detailed investigation of mortality patterns for individual age-groups by local authority. During the initial processing stage, a computer programme was run to produce detailed tabulations of the annual mortality for each local authority during the five year period 1963-67. In addition to a simple statement of the number of deaths by sex, age-group and disease category, a second tabulation was produced showing age- and sex-specific mortality rates per 100,000 population for the same headings. A summary table was also provided in each case, showing deaths by age-group for the five major mortality groupings. A sample of the output from this programme is shown in figure 8.3.

Unfortunately, a subsequent attempt at mapping the age- and sex-specific mortality rates for the county revealed substantial limitations in the base data, particularly in the case of the smaller local authorities. Despite the investigation of a five year sequence of mortality statistics, the numbers of deaths registered in particular age and sex categories were too low to permit reliable mapping, except perhaps in the case of the two most significant causes of death - viz. coronary disease and vascular lesions of the central nervous system. However, even in these two cases mapping of the data would only have been possible for a very limited number of age-groups.

As a result, it was decided to undertake the mapping of the mortality data by means of standardised mortality ratios (S.M.R.). In this way, it was found possible to consider the total mortality (all ages) for individual areal units, while at the same time allowance could be made for local variations in demographic structure. In essence, the operation seeks to view the mortality experience of a number of different areas in relation to a common or mean age and sex structure. This may be accomplished in one of two ways: the advantages and disadvantages of which are discussed below.

8.3.1. The indirect method of standardisation

This particular method of standardisation formed the basis of the mortality studies undertaken by Howe (1963 and 1970) for the United Kingdom; and Learmonth and Nichols (1965) and Learmonth and Grau (1969) in Australia. It is invariably employed where, at the local level, a detailed breakdown of deaths by age-group is not readily available. For example, in the case of England and Wales, a comprehensive age breakdown of annual deaths is only provided for the standard regions and major conurbations. Published mortality records at the county and county borough level simply consist of a statement of the total number of deaths by major

cause for each sex (see the Registrar General's Statistical Review, part 1. Tables. Medical).

As may be seen from table 8.1., the method involves the calculation of the number of deaths which would be expected to occur if the local population was to experience the age- and sex-specific mortality rates recorded for the overall or 'reference' population. The resultant figure is then divided into the total number of deaths which were actually recorded in the local area, to produce the S.M.R.. This is usually multiplied by a factor of 100 in order to express the ratio as a percentage.

A major advantage of the method lies in the fact that only a single set of age- and sex-specific mortality rates have to be calculated for each disease studied - i.e. for the 'reference' area only. All that is required at the local level is an appropriate breakdown of the population by age and sex (readily obtainable from the decennial census returns) together with the total number of deaths recorded for the particular cause of death under consideration.

On the other hand, it should be noted that substantial variations in the age-specific mortality rates for the local area are automatically excluded from consideration. In the example cited (table 8.1.) the mortality rates for males in the age-groups over 45 are substantially higher for County Durham than for England and Wales as a whole, although this fact is not appreciated in the subsequent computation of the S.M.R. In effect, the indirect method of standardisation is employed on the basic assumption that there are in fact few or no significant variations in the local age- and sex-specific rates.

8.3.2. The direct method of standardisation

In this case, the age- and sex-specific rates for the local area are applied to the age structure for the reference area. This facilitates

M A L E S

AGE GROUPS (yrs)	1961 POPULATION (000's)		NUMBER OF DEATHS ALL CAUSES, 1963-67		MORTALITY RATES (per 1,000) - 1963-67	
	England & Wales	Co. Durham	England & Wales	Co. Durham	England & Wales	Co. Durham
	(a)	(b)	(c)	(d)	(e)	(f)
- 5	1,846	68.5	55,364	1,932	29.991	28.204
5 - 14	3,578	130.5	7,686	275	2.148	2.107
15 - 24	3,056	98.2	17,630	489	5.768	4.979
25 - 34	2,947	99.7	16,058	508	5.449	5.095
35 - 44	3,110	105.8	38,623	1,486	12.418	14.045
45 - 54	3,159	97.3	109,468	3,987	34.652	40.976
55 - 64	2,504	79.5	289,919	10,344	115.782	130.113
65 - 75	1,418	44.3	401,076	13,697	282.846	309.187
75+	684	20.3	479,487	14,828	701.004	730.443
All ages	22,304	744.1	1,415,311	47,546	63.455	63.897

DIRECT METHOD OF STANDARDISATION

To Calculate:- The number of deaths which would be expected to occur if the age-specific mortality rates for County Durham were applied to the age-and sex-structure of the population for England & Wales.

AGE GROUP (yrs)	ESTIMATED NO. OF DEATHS
- 5	52,064.6
5 - 14	7,538.8
15 - 24	15,215.8
25 - 34	15,014.9
35 - 44	43,680.0
45 - 54	129,443.2
55 - 64	325,803.0
65 - 74	438,427.2
75+	499,623.0
All ages	1,526,810.2

$$\text{S.M.R.} = \frac{\text{Expected Deaths}}{\text{Actual Deaths}} \times 100 = \frac{1,526,810}{1,415,311} \times 100$$

S.M.R. = 107.87 (i.e. England & Wales = 100)

INDIRECT METHOD OF STANDARDISATION

To Calculate:- The number of deaths which would be expected to occur if the age-specific mortality rates for England & Wales as a whole were applied to the age- and sex-structure of the population for County Durham.

AGE GROUP (yrs)	ESTIMATED NO. OF DEATHS
- 5	2,054.4
5 - 14	280.3
15 - 24	566.4
25 - 34	543.3
35 - 44	1,313.8
45 - 54	3,371.6
55 - 64	9,204.7
65 - 74	12,530.1
75+	14,230.4
All ages	44,095.0

$$\text{S.M.R.} = \frac{\text{Actual Deaths}}{\text{Expected Deaths}} \times 100 = \frac{47,546}{44,095}$$

S.M.R. = 107.83 (i.e. England & Wales = 100)

the calculation of the expected number of deaths which would occur if the specific mortality rates for the local area were to be experienced over the reference area as a whole. This figure is then divided by the total number of deaths which were actually recorded in the reference area to produce the S.M.R. by direct standardisation. By this method it is possible to take account of local variations in age-specific mortality, as well as the local peculiarities of demographic structure.

It may be noted from table 8.1. that there was in fact little variation in the respective results obtained from the two methods of standardisation: indeed the two S.M.R.'s differed by less than 0.1 per cent. However, this situation should not be regarded as typical, and in practice the discrepancy between the two figures could well be substantially greater.

The direct method of standardisation cannot be employed unless an adequate age-breakdown of mortality is available at the local level. Fortunately this requirement was satisfied in the case of County Durham, even though the actual abstraction of the data from unpublished sources together with the initial processing of the statistics proved to be extremely time consuming. Moreover, it should be noted that this particular method of standardisation is also considerably more tedious in terms of computation than the indirect method already described. A completely new set of age- and sex-specific mortality rates has to be calculated for each local area in turn, and this process has to be repeated for each cause of death considered. For example, in the case of County Durham with forty local authorities, the investigation of mortality by sex and individual disease categories could well involve the computation of over 2,700 separate S.M.R.'s, each of which would require a different set of age- and sex-specific mortality rates. Quite obviously this would demand the expenditure of an exorbitant amount of

time and effort should the computation be undertaken by hand, or even by desk calculator. As a result a further computer programme was devised to transform the raw data, stored on magnetic tape, into standardised mortality ratios by local authority in a single process. A listing of the programme is provided in Appendix F. In this case, County Durham was regarded as the standard or 'reference' area, and the mortality for each of the individual local authorities was duly standardised in relation to the population structure for the county as a whole.

8.4. Spatial considerations

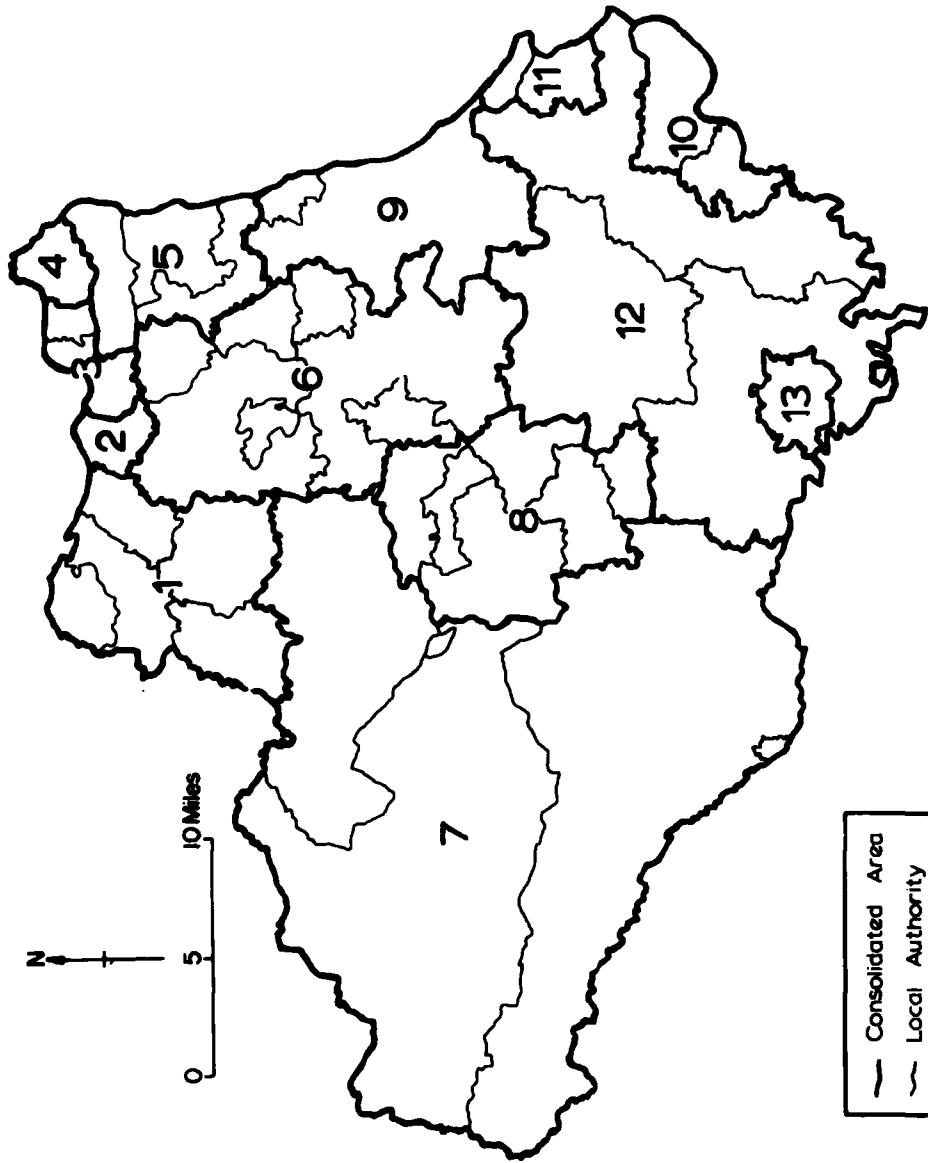
8.4.1. Boundary changes

During the period 1963-67 a number of administrative boundary changes took place within County Durham. Of these two produced quite marked fluctuations in the resident populations of the local authorities concerned. On April 1st 1967, the rural district of Sunderland, with a 1961 population of 28,368, was incorporated into the county borough of Sunderland and the urban district of Houghton-le-Spring. By far the larger part of the population was assigned to the former authority.

A second major boundary change also took effect from 1st April 1967. This involved the amalgamation of the County Borough of West Hartlepool and the adjacent Municipal Borough of Hartlepool with resident populations of 77,035 and 17,675 respectively (1961 census). The resultant authority was renamed the County Borough of Hartlepool.

In the case of both these boundary changes, it was decided to regard the pre-April 1967 situation as the base for the present investigation of mortality. Accordingly, appropriate statistical adjustments were made to the mortality data of all local authorities affected by the above changes. This operation was carried out at the same time as the standardisation processes described above (section 8.3.).

CONSOLIDATED AREAS FOR Co. DURHAM



No.	CONSOLIDATED AREA	L.A.'s INCORPORATED
1	NORTH WEST DURHAM	Blaydon, Gateshead, Houghton, Leazes, Merton, Ryburn, St. Andrew's, Whickham, etc.
2	GATESHEAD	Gateshead, etc.
3	CENTRAL TYRESIDE	Felling, Gateshead, etc.
4	SOUTH SHIELDS	South Shields, etc.
5	WEARSIDE	Sunderland, etc.
6	NORTH CENTRAL DURHAM	Chester-le-Street, etc.
7	WESTERN DURHAM	Barnard Castle, etc.
8	CENTRE WEST URBAN	Blaydon, etc.
9	DARLINGTON & DEANMAN	Darlington, etc.
10	NORTH TYRESIDE	etc.
11	EAST DURHAM	etc.
12	CENTRE EAST URBAN	etc.
13	DARLINGTON	Darlington, etc.

Figure 8.4.

8.4.2. Consolidation of local authorities

Soon after the initial processing of the raw data, it became apparent that mapping of the resultant S.M.R.'s for individual causes of death could not be undertaken at the local authority level except in the case of the most common disease categories - notably coronary disease and vascular lesions of the central nervous system. Despite the consideration of a five year period, the number of deaths recorded for less common disease categories at the local level were insufficient to permit mortality mapping with any degree of statistical confidence. This consideration had a particular relevance for the many local authorities of central and western Durham where resident populations were generally under 15,000.

Consequently it was decided to undertake a process of progressive compounding of the less populous local authorities to facilitate the mapping of the less common disease categories. In this connection, a figure of twenty recorded deaths (for the period 1963-67) was adopted as a required minimum in each areal unit for any given cause of death. This was consistent with the observations of the Registrar General that rates calculated on the basis of less than twenty cases are generally not statistically reliable (Howe, 1963:6). A more rigorous testing of the base data was not deemed necessary on this occasion, since the resultant mortality patterns were required merely as primary indicators of spatial variation. They were not to be regarded, necessarily, as a basis for more sophisticated synthesis.

Wherever possible, the process of consolidation took place between contiguous authority areas, and an attempt was made to amalgamate areas of a similar environmental character - e.g. the rural districts of western Durham, and the small urban districts of south-west Durham (figure 8.4.). Nevertheless, it should be stressed that since the act

of consolidation was carried out in a somewhat arbitrary fashion, a considerable measure of geographical sensitivity was inevitably removed from the spatial patterns of mortality which were subsequently derived. As a result of consolidation, the forty administrative units of the county were rationalised to thirteen consolidated areas, each with a resident population in excess of 20,000. A similar method of approach was applied by Hechter and Borhani (1965:12) in their study of mortality and geographic distribution of arteriosclerotic heart disease. In this case the statistics relating to 19 sparsely populated counties in California were compounded.

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Chapter 9Mortality Patterns in County Durham, 1963-67⁽¹⁾

This chapter is concerned with the preliminary consideration of the more significant aspects of mortality in County Durham. S.M.R.'s for eight mortality categories, together with 'death from all causes', were mapped for males and females for the five year period 1963-67. In the case of vascular lesions, and angina and coronary disease, it was possible to undertake mapping at the local authority level, since a sufficiently large number of deaths had been recorded for each authority area. However, in the case of the other six mortality categories it was found necessary to map on the basis of the 'consolidated areas' (described in section 8.4., supra). In each case, appropriate demographic cartograms were constructed and located on the page facing the corresponding chorographic maps. This ensured that undue attention was not paid to the sparsely populated rural areas to the west; as well as helping to emphasise the true quantum of mortality experienced in the urban areas.

The major features of the patterns of mortality are described and analysed, and an attempt made to view the Durham situation in relation to the mortality experience for England and Wales as a whole. Where the spatial patterns of mortality are particularly well-defined, a tentative attempt at causative explanation has been made; but only in those cases where the results would appear to be consistent with established medical theory or experience.

(1) The results, contained in this chapter, have already been published (Young 1970). The author wishes to express his sincere thanks to J.C. Dewdney, the editor of the British Association handbook, "Durham County and City with Teesside", for permission to reproduce the chorographic maps (figures 9.2., 9.4., and 9.6.).

9.1. Mortality from all causes

During the five-year period 1963-67 a total of 87,702 deaths were recorded in County Durham, comprising 47,546 male and 40,156 female deaths. The standardised mortality ratios for County Durham in relation to the rest of England and Wales were 109.5 and 110.3 for males and females respectively. This indicated that mortality rates were approximately 10 per cent above the national average when due allowance had been made for difference in age structure.

When age-specific mortality rates are considered (Table 9.1.), it may be seen that County Durham exhibits a significantly different regime from England and Wales as a whole. In the case of males, the county has a notable excess of mortality in the first five years of life, compared with the national average, followed by a period of relatively low mortality in the age range 5-35. Over the age of 35, the significant excess of mortality becomes re-established. In contrast, female mortality in County Durham appears to diverge less significantly from the regime of the country as a whole. Indeed, up to the age of 35, the age-specific rates are approximately the same for corresponding age groups but, over 35, the County Durham rates move to a relatively higher level of mortality, although the excess is not nearly so marked as in the case of males.

In all age groups, the age-specific mortality rates for females are substantially lower than those recorded for males. Indeed in the case of the 55-64 age group, the female mortality rate is less than half that of the male rate.

Although in the case of individual disease categories significant spatial distributions are prominent (see below), the mapped S.M.R.'s for all causes display less well-defined patterns (figs. 9.1. and 9.2.).

Table 9.1. Mean annual age-specific mortality rates per 100,000 persons from all causes for County Durham and England and Wales, 1963-67.

Age Group (Yrs)	MALES		FEMALES	
	County Durham	England and Wales	County Durham	England and Wales
0-5	826	598	470	472
5-14	42	43	26	28
15-24	100	115	43	47
25-34	102	108	68	69
35-44	281	249	199	173
45-54	819	693	469	417
55-64	2,614	2,311	1,197	1,081
65-74	6,183	5,649	3,488	3,013
75+	14,611	14,103	12,038	11,105

Only the rural districts of Leamchester, Sunderland and Darlington had S.M.R.'s significantly above the county mean for both males and females, and only Consett U.D. and Barnard Castle R.D. had significantly low S.M.R.'s for both sexes. In the case of males, Gateshead and Felling formed a consolidated area of high mortality in the north of the county, together with the more isolated centre of Chester-le-Street U.D. For females, an extensive area of high mortality was visible in the rural districts of the south and east of the county, whilst Hartlepool M.B. and Whickham U.D. displayed surprisingly low levels of mortality.

9.2. Angina and Coronary Disease

During the five-year period 1963-67, angina and coronary disease accounted for approximately 25 per cent of all male and 19 per cent of all female deaths in County Durham. As such it was the main cause of death for both sexes. ⁽¹⁾ The standardised mortality ratios for the county as a whole were 112 and 131 for males and females respectively,

(1) Howe (1963:43) reported that during the 1954-58 period arteriosclerotic heart disease was the main cause of deaths in males, and only the second most important in females.

Figures 9.1. and 9.2. Mortality from all causes,
vascular lesions, and angina and coronary disease,
1963-67. (Standardised mortality ratios for each
local authority area : County Durham = 100.)

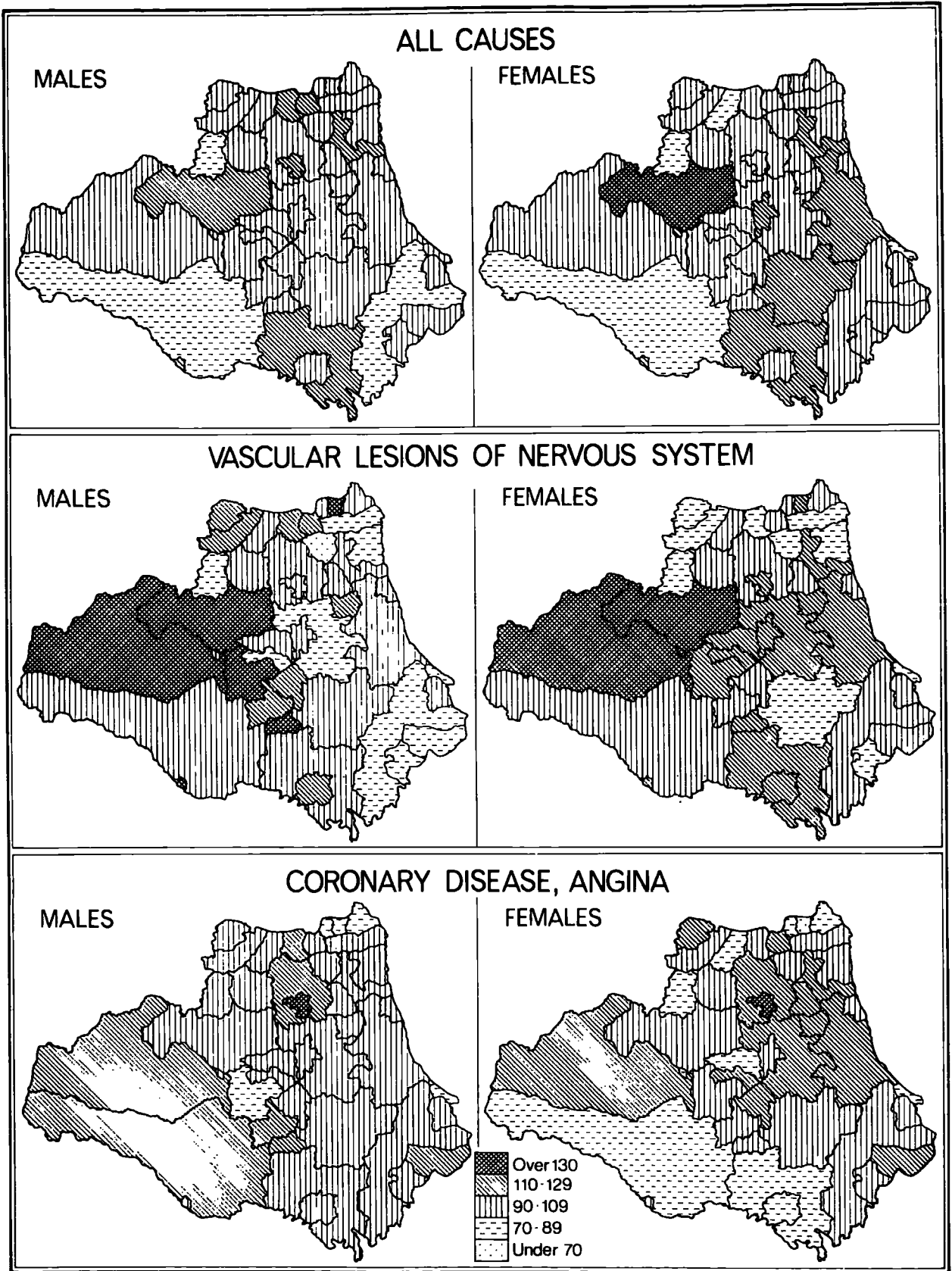


Figure 9.2.

indicating a marked excess of mortality in comparison with the rest of England and Wales, particularly as far as women were concerned.

In the case of males, three distinct areas exhibited high S.M.R.'s (figures 9.1. and 9.2.). These were the Chester-le-Street to Gateshead area in the north, the south-western rural areas of the county, and Billingham U.D. In contrast, the local authorities of south-east Tyneside, together with Hartlepool M.B. and Crook U.D., had S.M.R.'s significantly below the county mean.

The pattern of female mortality, on the other hand, showed an extensive area of high incidence in the centre-east of the county, surrounded by a ring of additional areas - Billingham, Felling and Ryton U.D.'s and Weardale R.D. - with S.M.R.'s in excess of 110. South-east Tyneside, together with a zone in the south-west of the county, constituted the most significant areas of low mortality, although the local authorities of Hartlepool, Whickham, Consett and Brandon also recorded relatively low ratios.

9.3. Vascular lesions of the Central Nervous System

Between 1963 and 1967 vascular lesions of the central nervous system accounted for 11 per cent of all male deaths and approximately 17 per cent of female deaths. However, this sex differential is perhaps not quite so dramatic as it might at first appear, since over 50 per cent of the deaths from this cause occur in the age-group 75 and over, in which there is a remarkably high sex-ratio. During the five-year period under consideration, County Durham experienced a particularly high level of mortality from this disease, as compared with the rest of England and Wales. The S.M.R. for males was 129, whilst the corresponding figure for females was 123.

Within the county, the mapped S.M.R.'s show a considerable measure of spatial variation, even within quite short distances (figs. 9.1. and 9.2.).

The area of highest incidence in the case of males was located towards the west of the county in the rural districts of Lanchester and Weardale, together with the urban districts of Crook and Shildon. In contrast, Wearside, North Teesside, including Stockton R.D., Consett and Durham R.D. exhibited relatively low mortality ratios.

A similar area of high mortality, covering Weardale and Lanchester rural districts, was noted in the map of female mortality from this cause. However, in this case a belt of relatively high mortality (S.M.R. 110-130) was seen to extend as far as Easington on the coast. In contrast, the most significant areas of low mortality were to be found in the north of the county, particularly at Gateshead, Sunderland and Consett, while Hartlepool M.B., Sedgefield R.D. and Stockton M.B. constituted isolated areas of low mortality in the south.

At a national level, the work of Morris et al. (1961), suggested that there was an inverse relationship between the hardness of water supplies and the level of mortality from cardio-vascular disease (including vascular lesions). Since the greater part of County Durham is served with supplies of soft drinking water derived from peat-lined reservoirs in the Pennines, the above hypothesis might seem to be substantiated by the high S.M.R.'s for the county as a whole. However, when the situation is analysed at the local level, it is discovered that the areas with the highest mortality ratios (particularly Weardale and Lanchester) are in fact the very areas served by local supplies of extremely hard spring water. Quite obviously, at the local level of investigation, an alternative hypothesis of causation must be sought.

9.4. Cancer of the Stomach

Cancer of the stomach accounted for only about 3 per cent of all deaths recorded in County Durham between 1963 and 1967. Nevertheless, in comparison with the rest of England and Wales, the county experienced

Figures 9.3. and 9.4. Mortality from specific categories
of malignant disease, 1963-67. (Standardised mortality ratios
for groups of local authority areas; County Durham = 100.)

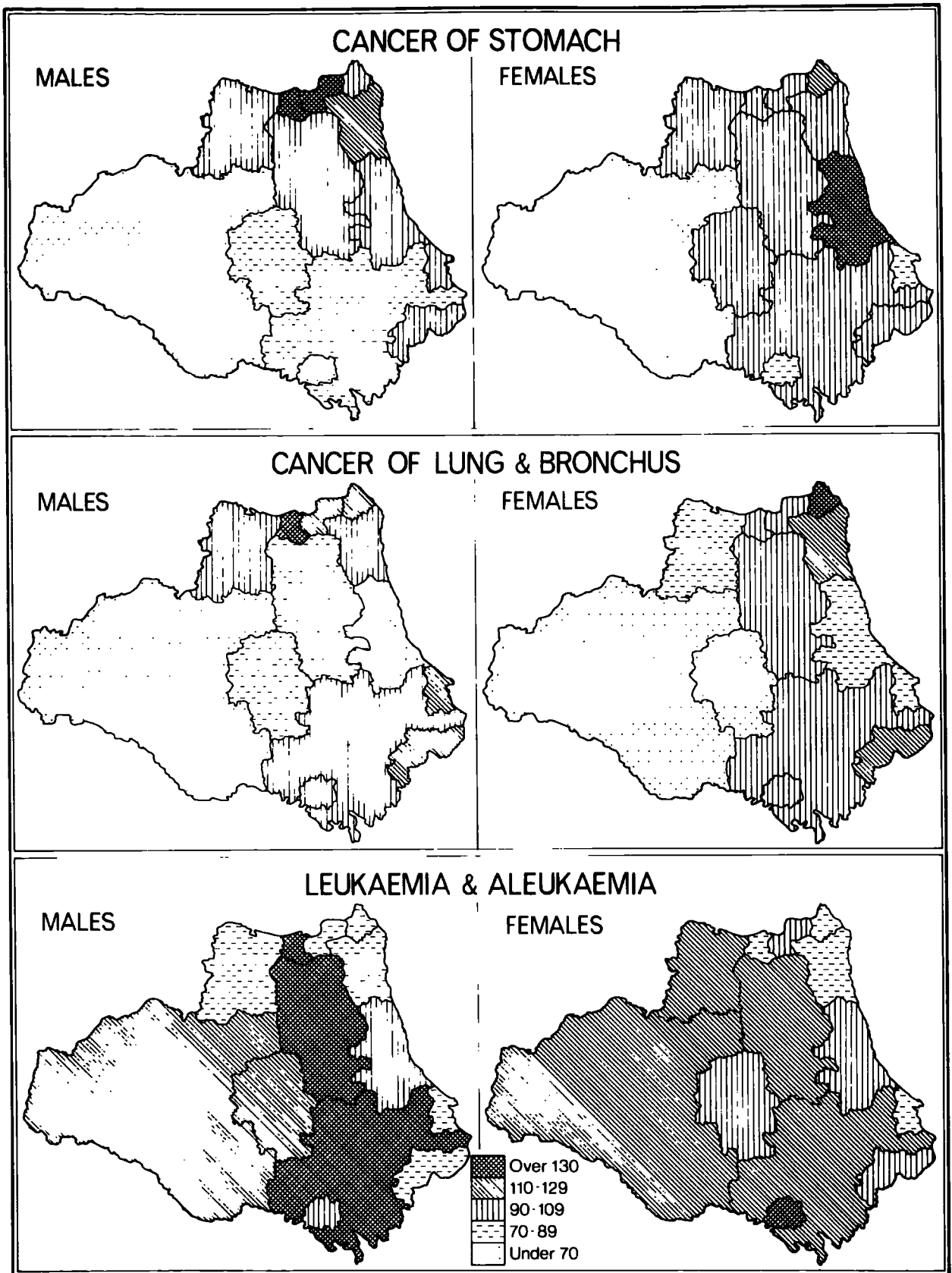


Figure 9.4.

particularly high mortality ratios. The S.M.R.'s were 136 and 143 for males and females respectively.

In figures 9.3. and 9.4., the appropriate S.M.R.'s have been mapped for the consolidated areas of the county. For males, a quite distinctive trend is discernible, with the areas of extremely low S.M.R.'s (less than 70) in the west and south-west of the county, and the areas of highest incidence in the north and east. By comparison, the female distribution exhibits a more direct west to east gradient, with Easington and Seaham as the area of maximum incidence. Hartlepoons and Darlington, however, return relatively low S.M.R.'s.

A considerable number of environmental and genetic factors have been put forward to explain the geographical variation of carcinoma of the stomach. However, as yet no single factor has gained general acceptance as the probable causative agent (Maddock, 1966). Nevertheless, the findings of Winkelstein and Kantor (1969) that there is a positive correlation between the incidence of stomach cancer and particulate air pollution may well be shown to have a bearing on the situation in County Durham. This is particularly true, in the case of male mortality, where the area of highest mortality - South Tyneside - coincides with the area of heaviest smoke pollution.

9.5. Cancer of the Lung and Bronchus

Lung cancer is invariably more prevalent amongst men, which tends to suggest a physiological difference rather than an effect of environment. In County Durham, the disease category accounted for 7.8 and 1.4 per cent of the total deaths for males and females respectively during the five-year period under consideration. An S.M.R. of 114 for males indicated the incidence for the county was substantially above that for England and Wales, whilst a corresponding figure of 95 for females indicated a slightly lower level of mortality.

When the geographical distribution of the disease is analysed within the county, the situation is seen to be similar to the one already seen in the case of stomach cancer, although not quite so straightforward. In particular, the same west to east gradient is apparent for both sexes (figures 9.3. and 9.4.).

In the case of males, the zones of heaviest particulate air pollution correspond to the areas of highest incidence - namely, Tyneside, Hartlepool and North Teesside. Stocks (1966), in his epidemiological studies on lung cancer, noted the considerable rural-urban differences within the Northern Region in respect to this disease. By eliminating the differential effects of smoking and social class, it was concluded that "at ages over 45 the high urban ratios for lung cancer are inexplicable apart from air pollution" (p.613).

An interesting anomaly to this is provided by the Easington and Seaham areas, which experienced surprisingly low mortality ratios (less than 70). However, this phenomenon could well be explained in terms of the particular importance of coal-mining within this-area. As Ashley (1968) comments, "The frequency of death from carcinoma of the lung is lower in workers in the coal-mining industry than in other groups of men of comparable age." It is postulated that the effects of fibrosis in the lung associated with the mining disease pneumoconiosis could well act as a 'defence mechanism' against the incursion of lung cancer.

For females, the area of highest incidence is located in the extreme north-east of the county, and centred on South Shields and Sunderland, with a more minor concentration in North Teesside.

9.6. Leukaemia and Aleukaemia

Although leukaemia may be considered one of the more minor causes of death - accounting for less than one half per cent of all deaths - the

Figures 9.5. and 9.6. Mortality from specific categories of respiratory disease, 1963-67. (Standardised mortality ratios for groups of local authority areas; County Durham = 100.)

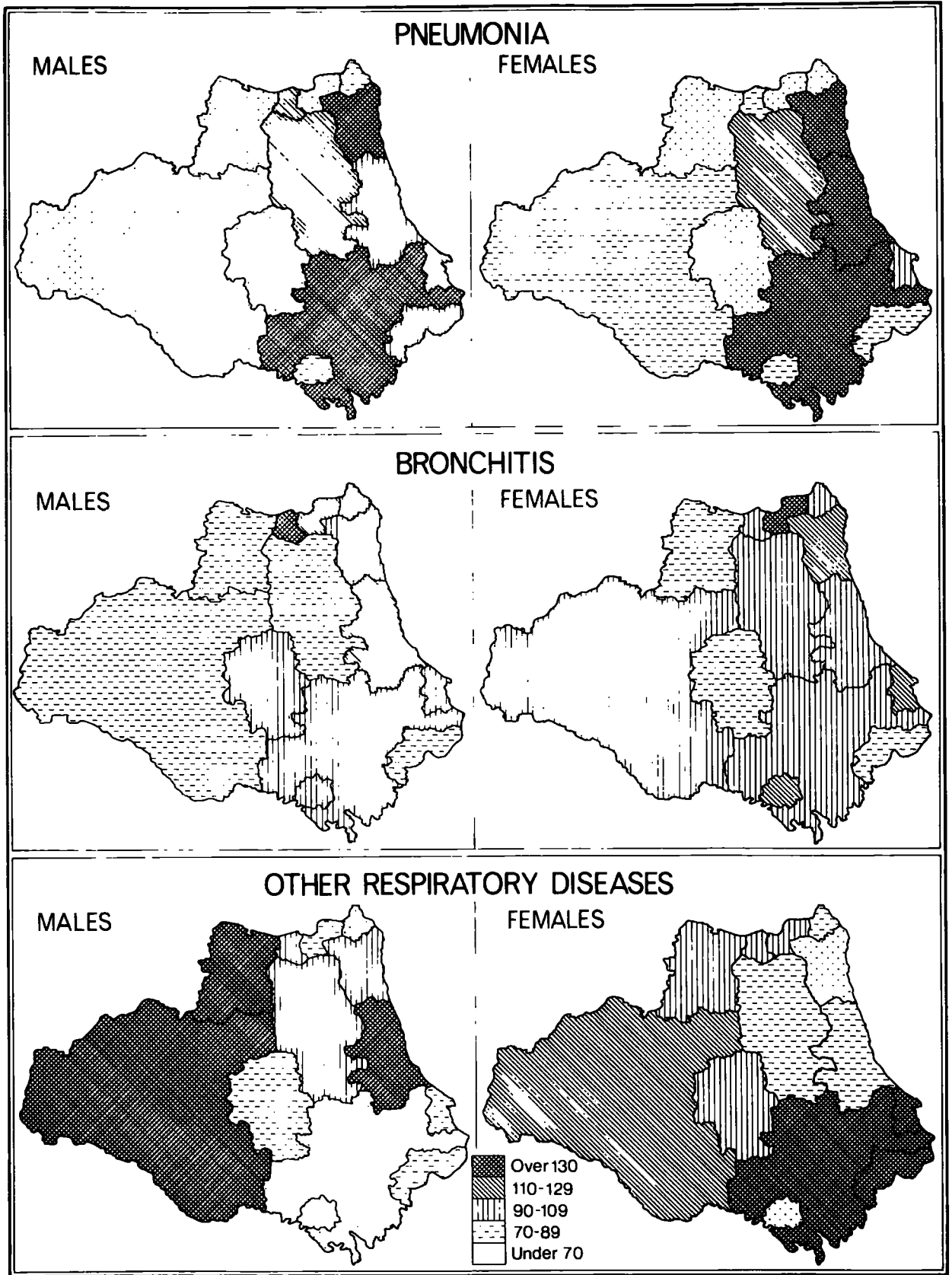


Figure 9.6.

incidence of the disease appears to be increasing quite dramatically at the present time, particularly in the wealthier and more advanced areas of the world (Dowsett 1966). In this connection it is perhaps interesting to note that County Durham experienced a significantly lower incidence of the disease than other more prosperous areas of the country. The S.M.R. for males was 89, while for females the figure was 90.

The geographical variation of the disease within the county (figures 9.3. and 9.4.) indicates an essential similarity in the distribution for both sexes. In particular, the more heavily industrialised areas of the county - namely South Tyneside, Wearside and Hartlepoons - with less attractive social environments, exhibit substantially lower S.M.R.'s than the average.

In the case of male mortality, the area of highest incidence is located in a north-south belt, from Gateshead in the north to Darlington R.D. in the south. For females, the County Borough of Darlington had the highest level of mortality (S.M.R. 151), although the greater part of central and western Durham also displayed above-average ratios (over 110).

9.7. Bronchitis

As in the case of lung cancer, bronchitis is a far more significant cause of death among men than women. In County Durham, during the five-year period under consideration, the disease accounted for 8.7 per cent of the total number of male deaths, and only 3.7 per cent of the female deaths.

Compared with the rest of England and Wales, County Durham's experience was substantially worse than the national average, with S.M.R.'s of 120 and 123 for men and women respectively. This appeared to be consistent with the findings of Ashley (1967) that the role of bronchitis

as a cause of death appeared to be enhanced "in those areas of the country in which coal-mining and the textile industries are concentrated'.

Within the county (figures 9.5. and 9.6.), Tyneside was seen to be prominent in both maps. In the case of males, Gateshead constituted the area of maximum mortality, with central Tyneside, and the Easington and Seaham areas also displaying above-average mortality. On the other hand, much of the north-west and west of the county, together with north Teesside, experienced below-average mortality ratios. For females, the situation was substantially different. Central Tyneside appeared as the area of highest incidence, with Wearside, Hartlepool and Darlington also showing a tendency towards high levels of mortality. In contrast, north Teesside once again exhibited a surprisingly low S.M.R.

The relationship between bronchitis and particulate air pollution has already been well documented by a large number of workers, such as Daly (1959) and Pemberton and Goldberg (1954). This relationship appears to have a considerable relevance to the situation in County Durham, where the areas of highest mortality from bronchitis seem to correspond remarkably well with the zones of heaviest atmospheric pollution.

9.8. Pneumonia and Broncho-Pneumonia

Death from this cause may result from either a primary infection of pneumonia, or as a secondary complication of a number of other disorders. In the case of women, pneumonia is the most important cause of death of all respiratory diseases, accounting for approximately 6.5 per cent of total deaths. For men, it ranks third (after bronchitis and lung cancer) with a share of approximately 5.5 per cent of all deaths. During the period 1963-67, County Durham as a whole recorded S.M.R.'s of 111 and 108 for males and females respectively, indicating an excess of mortality in the order of 10 per cent over the national mean.

An analysis of the situation within the county (figures 9.5. and 9.6.) reveals an overall west to east trend in the distribution, as in the case of stomach cancer discussed above. For males the whole of the western portion of Durham, together with central Tyneside, experienced S.M.R.'s 30 per cent or more below the county mean. Wearside and the south-east rural districts on the other hand had mortality ratios considerably above the county mean (130 and over).

Female mortality from pneumonia displayed a similar spatial variation, although the pattern was not so well-defined as in the case of males. The whole of Southern Tyneside and north-west Durham, together with the south-west urban areas of the county, represented the main areas of low mortality, whilst a contiguous area in the east, extending from Wearside in the north to Darlington R.D. in the south, constituted the major zone of high mortality ratios.

9.9. Other Respiratory Disease

Although the number of deaths in this residual category represents but a small fraction of the total mortality from respiratory disease, the geographical variation of mortality within County Durham (figures 9.5. and 9.6.) was deemed to warrant further comment.

In complete contrast to the other respiratory diseases already considered, male mortality from this cause was seen to be high in the west and north-west areas of the county, and surprisingly low in much of Tyneside, and south-east Durham. For females, a similar although less distinct pattern was discernible. The south-east of the county had S.M.R.'s over 30 per cent above the mean, whilst the western rural areas also showed a marked excess of mortality. Once again, the more polluted areas of the county to the north and east recorded surprisingly low levels of mortality - particularly Wearside with an S.M.R. of only 66.

It would therefore appear that a more sophisticated aetiological mechanism than mere air pollution would have to be invoked to explain these rather anomalous patterns produced by this supposed 'residual' category of respiratory diseases.

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Chapter 10Conclusion

Although the more important findings and results have been discussed in some detail at the end of individual chapters, it is perhaps useful to summarise here these main conclusions in order to view them in the context of the study as a whole. At the same time, the initial aims and objectives of the thesis, outlined in Chapter 1, are now here reassessed in the light of subsequent research experience. It is moreover possible to evaluate the significance and measure of success of the study bearing in mind the numerous difficulties that were encountered in carrying out the research programme.

It had originally been proposed to attempt a comprehensive survey of the medical geography for the whole of North-East England, comprising the geographical counties of Northumberland, Durham and the North Riding of Yorkshire. It was soon realised, however, that this would prove to be completely impracticable because of the limitations of both time and resources. As a result, a compromise solution was accepted whereby County Durham was adopted as the study area. This enabled a more detailed approach to be made for a wider range of morbidity and mortality experience, but over a much smaller study area territorially. Nevertheless, this process of rationalisation does not appear to have had a proportional effect upon the validity or relevance of the resultant survey, since, as has been pointed out in section 1.5. supra, County Durham embraces most of the environmental facets which characterise the North East as a whole.

In approaching the field of medicine for the first time, the geographer invariably experiences a sense of uneasiness. This stems partly from a total unfamiliarity with the subject matter and associated vocabulary, and partly from a sudden awareness of the enormity

of the field, encompassing as it does not only disease epidemiology, but also the related topics of the location, provision and spheres of influence of hospitals and associated medical facilities. This latter consideration may be conveniently coped with by exercising a measure of selectivity in the initial choice of topics for investigation. In undertaking research for the present thesis it was soon realised that it would only be possible to consider a very limited number of aspects of the morbidity and mortality pattern. However this did not solve the other problem which arose from an unfamiliarity with the overall field of medicine. Indeed a considerable amount of time was consumed during the initial stages of the research in background reading so that the more fundamental concepts and theories of the discipline could be grasped. In addition the study of each different disease category demanded a systematic search for a totally new set of bibliographic references to provide a suitable framework of basic medical information with which to approach the study. In the case of tuberculosis for example, approximately 200 references were initially sifted during the preliminary stages of enquiry. Quite obviously, in most cases only a very limited number of key references provided the necessary framework for the study, but this did not effectively reduce the amount of preparatory work involved. At the same time, a preliminary search for data revealed the existence of a number of prolific sources, many of them unpublished, which so far do not appear to have been seriously considered by the geographer. This discovery lent added purpose and incentive to the study.

Disease mapping at the county scale proved generally successful and rewarding. In many cases marked spatial anomalies in the disease pattern, which could hardly have been distinguished at the national level, were readily identifiable, and could be subjected to more

intensive study. The analysis of suspected food poisoning cases at Consett is a case in point. Nevertheless, mapping at this scale did present a number of problems; the chief of which was associated with the conflict which arose between the desirability of mapping at the smallest areal unit and the need to retain statistical significance and meaningfulness in the resultant patterns.

The geographical investigation of mortality at this intermediate scale proved to be substantially less satisfactory than at the national level (see for example Howe 1970a). This was due to the relatively small number of deaths recorded for many disease categories even for a five year period. As a result it was found necessary to compound the mortality figures from some of the smaller local authorities into consolidated areas, although this tended to reduce the areal sensitivity of the resultant patterns in an effort to retain statistical significance. At the same time, increasing mobility of the population at risk, coupled with the complexity of causation in the case of most degenerative disorders, makes subsequent analysis and interpretation of the resultant patterns extremely uncertain. Indeed, attempts at more sophisticated synthesis of the standardised mortality ratios for the local authority areas of County Durham were frustrated. Simple and multiple correlation techniques as well as factor analysis were employed with only a limited measure of success. For this reason, only the broad patterns of mortality are mapped and discussed in Chapter 9. Notwithstanding these limitations, however, some interesting spatial patterns did emerge from the study of mortality, particularly in the case of vascular lesions, cancer of the stomach, cancer of the lung and also bronchitis.

In contrast, the mapping of morbidity at the county or intermediate scale proved to be substantially more profitable, despite the previous experience of such workers as Howe who has stated that morbidity mapping,

although desirable, is not practicable under present circumstances "since there are no data available on a national basis for plotting" (Howe 1970b). And Stamp (1964:18) comments that "it is far more difficult to construct morbidity maps [than those] for mortality." It is of course true that a considerable number of maps were constructed during the preliminary stages in the investigation of morbidity which defied rational explanation or interpretation. These were subsequently abandoned in favour of maps for those disease categories which were regarded as more promising from a geographical point of view. It is also true that by virtue of the limited range of diseases which are officially notifiable, the initial choice is somewhat restricted. Nevertheless, the results obtained from the individual studies of both measles and tuberculosis suggested that this type of approach was worthwhile, and that there was in fact a vast store of official morbidity statistics, both published and unpublished, that cried out for analysis by the geographer.

During the initial stages of the research programme a number of cartographic techniques were devised to assist in the particular task of disease mapping. The most important of these was the demographic map for County Durham, a type of cartogram which has been employed throughout this thesis in conjunction with the more familiar chorographic base. The necessity for incorporating such a demographic perspective in this type of study may be justified in terms of the medical geographer's concern with the 'population at risk' and not merely with the areal extent and shape of the local districts being mapped. Very often the quantum of disease - i.e. the absolute number of deaths or notifications - is an equally significant dimension of the disease pattern as intensity of infection, usually expressed as the number of cases per unit of population. This is particularly relevant in the case of County Durham, where the extensive yet sparsely populated rural districts in the west of the

County tend to dominate the conventional chorographic base map at the expense of the areally more compact urban areas to the east, which contain the bulk of the County's population.

The concept of the demographic perspective was taken a stage further in the construction of the 'epidemograph'; a physical model developed principally in an effort to reduce the time taken in hand-mapping the large number of disease maps. At the same time, it was hoped that this technique would help to reduce the somewhat misleading visual impression created by choroplething for a set of discrete class intervals.

The computer has also had an invaluable role to play in the preparation of this thesis. Indeed it may be said that without such assistance it would have been impossible to tackle the sheer bulk of data involved, or to undertake the subsequent manipulation and computation of the statistics. The contribution made by the computer may be conveniently divided into three main areas: firstly, computer graphics; secondly, basic handling, checking and storage of data; and thirdly rapid statistical calculation.

Disease mapping by computer enables the geographer to obtain a rapid visual representation of areal statistics, without resort to laborious hand-shading. It was found that this method had a particular application to the study of the spatial diffusion of epidemic diseases such as measles, where a whole series of distribution maps might be required to represent the spread of disease at regular time intervals. Although the particular computer programme described in Chapter 3 was specifically devised for the mapping of disease in County Durham, it may be conveniently adapted for use in mapping any number of different parameters for any given area. For example, the technique has already been successfully applied to the plotting of demographic and socio-economic parameters for the Iranian city of Isfahan (Power, personal communication).

The second major application of the computer lay in the preliminary handling, manipulation and storage of large data sets. This was particularly important in Section III, which was concerned with mortality, where for the five year period under consideration (1963-67) it was necessary to transcribe a total of approximately 175,000 items of data from the official records of the county and local health departments. These data were subsequently transferred to computer cards. During this double process a number of copying and punching errors were inevitably introduced. A simple computer programme was therefore written to detect such errors by a process of cross-checking all the additions for individual columns and rows with their respective sub-totals. When all such errors had been eliminated, an appropriate print out of the data was obtained for reference purposes, and then the complete data bank was placed on to magnetic tape. In this latter form, the total mortality experience for County Durham for the five year period could be read into the computer in under two minutes, and individual items of data could be accessed in a matter of seconds. Quite obviously this obviated the need for protracted and laborious data abstraction by hand for each new set of statistical calculations.

Notwithstanding the importance of the above applications of the computer to the present study, the most significant contribution was effected in the area of statistical computation. In its simplest form this consisted of calculating notification or case rates for the notifiable diseases such as measles and tuberculosis. More sophisticated computer programmes were written to compute centroids, chi squares, coefficients of correlation and standardised mortality ratios (by the direct method of standardisation). In the case of the multiple regression programme, utilised in the investigation of tuberculosis (Chapter 5)

and the factor analysis programme which was applied unsuccessfully to the analysis of mortality, existing sub-routines (available in the IBM statistical package) were adapted and incorporated into substantially new programmes.

Without the aid of such computer techniques the bulk of the statistical computation reflected in the results of this thesis could not have been attempted in the time available. In particular the manual calculation of the standardised mortality ratios by the direct method of standardisation would have proved impossible, and in the case of tuberculosis, the depth of analysis would have had to be substantially reduced. Nevertheless, it should not be imagined that the application of rapid data handling and quantitative techniques to geographical studies of this type can of themselves yield fundamental hypotheses or theories. Mathematical manipulation can provide only the means and not the end. "Interpretation", Goodall (1952:195) insists "is still a process of the mind and while quantitative descriptions may greatly facilitate or even guide these mental processes, they cannot replace them."

Although no major or startling medical revelations have been made as a result of this particular research programme, the study has nevertheless suggested a number of promising hypotheses, worthy of further investigation. At the county level, atmospheric pollution emerged as a possible aetiological factor in the actual initiation or 'triggering' of individual measles epidemics. This may be regarded as being consistent with the findings of Papp (1956) that the measles virus enters an individual through the structure of the eye and not via the respiratory tract as originally thought. With a significant increase in the levels of atmospheric pollution, an aqueous discharge from the eye would be evoked in the susceptible population, thereby providing a very favourable environment for effective transfer to take place, particularly in the initial phases of epidemicity when 'seeding' may be regarded as an important

prerequisite. Alternatively, a significant rise in atmospheric pollution would elicit a higher incidence of other respiratory diseases, which would thereby lower the resistance of the susceptible population to measles.

At the local level, detailed mapping revealed an interesting distribution of suspected food poisoning cases in Consett, during the winter period 1964-65. In particular, the spatial distribution of those cases for which a substantive cause had not been established suggested that the large iron and steel works in the south-west of the urban district was in some way responsible. Indeed, further analysis of atmospheric pollution records for the relevant period supported the hypothesis that solid pollutants, and most probably the ubiquitous red iron ore dust, were acting as a significant aetiological factor in promoting this excess of stomach disorders. Furthermore, it is perhaps interesting to note that subsequent investigation of the contemporary records of suspected food poisoning and dysentery for Scunthorpe, another iron and steel town, revealed an almost identical seasonal distribution of cases, which contrasted sharply with the regime for England and Wales as a whole. Of course it is realised that without more detailed knowledge of the particular environmental circumstances of Scunthorpe, and a more careful investigation of the spatial distribution of cases within the town, it is perhaps unwise to draw more than tentative parallels with the Consett situation. Nevertheless this type of evidence did appear to lend added weight to the hypothesis that iron ore dust could well be implicated in the promotion of particular types of ill-defined stomach disorders. A copy of a paper setting out the major findings of the Consett study was requested by the M.P. for North-west Durham, Mr. David Watkins, and the matter was subsequently raised in the House of Commons on 3 February 1970 in a parliamentary debate on smokeless

zones and pollution.⁽¹⁾ Considerable comment and discussion was also generated in the local press and radio as a result of a paper presented at the Durham meeting of the British Association for the Advancement of Science (Young 1970). It is hoped that this study may indeed constitute "an important piece of evidence in the battle against the very serious pollution which arises from the steel works in Consett" (Watkins 1970).

Apart from the limited number of somewhat unexpected findings which emerged from the present study, most of the results and conclusions tended to concur very favourably with established epidemiological theory. In the case of measles, parameters of living density were shown to exert a significant influence in determining intensity of infection as well as the diffusion patterns for particular epidemic cycles. Whereas the major urban areas of the County (and especially south Tyneside and Wearside) were shown to be the initiators of epidemicity, it was the smaller nucleated settlements of central and south-west Durham that emerged as significant reservoir areas for the disease during the interepidemic periods. This latter fact has subsequently been corroborated by the more localised study of measles in the Sunderland area by Harper (1971).

In the case of tuberculosis, parameters of living density and particularly overcrowding were once again invoked to explain the broader patterns of morbidity. This could be explained partly in terms of the greater chance of effective contact taking place between the 'carrier' and the susceptible where living densities are high. Alternatively, the existence of high living densities (and particularly a high percentage of the population living in overcrowded conditions) might merely reflect the presence of poor living conditions favouring the perpetuation and effective transmission of the tubercle bacillus. Indeed subsequent analysis revealed

(1) House of Commons (Official Report) Parliamentary Debates for Tuesday, 3rd February 1970. Hansard Vol. 795 (No. 51) columns 319-322.

that whereas factors associated with living density could be held to explain the broader patterns of morbidity, the influence of socio-economic status and inferior housing conditions appeared to be extremely important at the local level.

However, a more detailed analysis of respiratory tuberculosis in south central Tyneside revealed a rather surprising anomaly to this theoretical model. For whereas the disease had originally been particularly prevalent in the worst areas of nineteenth century terraced housing (Bradbury 1933) a substantial migration of the disease had taken place during the Second World War. This had apparently occurred as a direct result of the rehousing of a substantial number of tuberculous families to modern estates on the outskirts of the existing urban cores, necessitated by the comprehensive programme of urban renewal carried out during the late 1950's and early 1960's. In the case of Jarrow M.B., there was in fact a statistically significant excess of cases recorded in the modern housing estates. This tended to suggest that slum clearance alone could not provide an immediate or complete solution to the tuberculosis problem. By virtue of its insidious nature the disease could well be expected to take a considerable period of time to respond to these dramatic improvements in the social environment of the area.

Section III concerned with the mortality patterns of County Durham emphasised two main points. Firstly, the mortality experience for County Durham was poor by comparison with the rest of England and Wales, with the notable exception of Leukaemia, and female mortality from cancer of the lung and bronchus. Cancer of the stomach emerged as the most significant cause of death in this respect, with S.M.R.'s for males and females 36 and 43 per cent above the national average, respectively. Mortality from vascular lesions of the central nervous system; bronchitis; and angina and coronary disease for males was 20-30 per cent higher in County Durham than for England and Wales; whilst death rates for

pneumonia; angina and coronary disease for females, and cancer of the lung and bronchus for males were 10-20 per cent higher. Secondly, the spatial variation of the S.M.R.'s within County Durham was found to be almost as large as between individual counties at the national scale. Indeed, most if not all of the mortality maps presented in Chapter 9 demonstrated substantial variations in mortality experience between individual local authorities or 'consolidated areas'. This was particularly true of deaths attributable to vascular lesions of the central nervous system, where S.M.R.'s for a number of local authority areas in the west of the County were up to 80% higher than the average for County Durham. In this case, differences in the hardness of domestic water supplies were thought to play a significant role in promoting these spatial anomalies. At the national level, in the United States and Great Britain, an inverse relationship was claimed between hardness of water supply and mortality levels from cardio-vascular disease (Schroeder 1960, Morris et al 1961). However, a more recent study at the local scale (Lindeman and Assenzo 1964) tended to favour a positive relationship between these two factors - i.e. high mortality rates from cardio-vascular disease are associated with areas of hardest water supplies. The evidence for County Durham would tend to support the latter hypothesis. In the case of mortality from lung cancer, bronchitis, high rates were recorded in the main urban areas of the County, and here atmospheric pollution was cited as probably the most significant aetiological factor. This is consistent with previous studies undertaken by such workers as Daly (1959). Furthermore, the work of Winkelstein and Kantor (1969) suggested that this same factor might also be having a significant influence on the mortality patterns for cancer of the stomach, particularly in the case of males.

"There is no doubt that the special techniques employed by the geographer would be of great assistance in the study of broad regional patterns (of disease) within which detailed sampling might be carried out," (Banks 1959:204). It is the role of the geographer to record the facts accurately on maps; to analyse the resultant distributional patterns; and then to propose what appear to him to be valid hypotheses. In undertaking the present study it has generally been possible to provide an answer to the question 'where?' by means of basic mapping of disease patterns. However, in only a few cases has it proved feasible to answer the further question 'why?' with any degree of certainty. Moreover, the constraints of time have meant that the present investigation has only been able to scratch the surface of such a wide topic encompassed by the title 'medical geography', even for such a relatively restricted study area as County Durham.

Notwithstanding these inherent difficulties, the study did provide an opportunity of demonstrating the type of contribution that the geographer is capable of making to the overall field of medicine, particularly at the intermediate scale of inquiry. In addition, the investigation has brought to light a number of significant and seemingly untapped data sources, which must surely deserve the attention of medical geographers in the future.

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APPENDICES

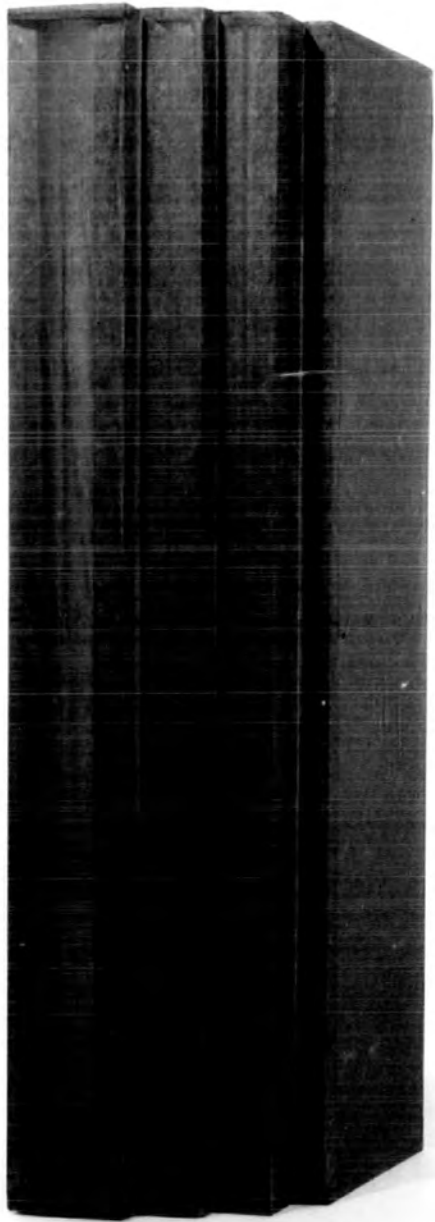
THE EPIDEMOGRAPH - CONSTRUCTION

Two large die-line copies of the demographic base map - constructed by a method used by Hunter and Young (1967) - were pasted on to two plywood sheets, measuring approximately 45" x 36". The templates of individual local authorities were then cut out by fret saw, and the outer rim retained as the 'base level' of measurement (A in Plate 1). Hardwood strips measuring 18" x $\frac{1}{2}$ " x $\frac{1}{2}$ " were then pinned to the corresponding pairs of 'jig-saw' pieces at each 'corner', to form a rigid framework (Plate 5(a)). At the same time, a suitable piece of backing wood was nailed to the base piece, and a suitable size of hole drilled in the bottom, to accommodate $\frac{1}{2}$ " or $\frac{1}{4}$ " dowelling at a later stage. Each framework or 'element' was covered with double-weight tissue paper, and steam-tightened (Plate 5(b)) before two coats of clear dope were applied to provide added strength and tautness.

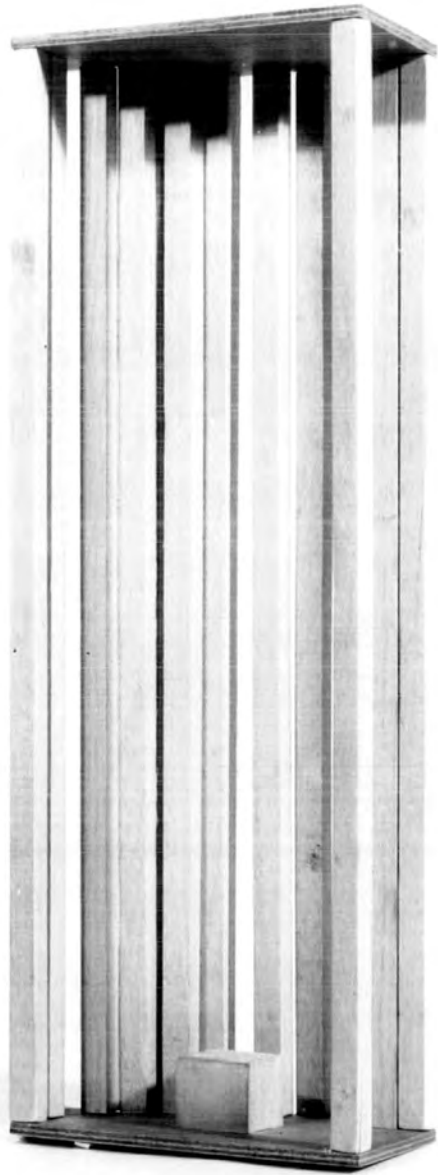
The outer box (B in Plate 1) was constructed from plywood sheeting secured to a $\frac{7}{8}$ " thick laminated base. The thickness of the latter was to offset the effects of warping induced by the combined weight of the 40 elements. Hinged side-flaps were also incorporated to enable easy access to the lower portions of the individual elements when the model was assembled. Four substantial legs were secured to the base, and the necessary strutting provided to render the structure completely rigid. In addition, ball-bearing castors were screwed into the base of each leg to facilitate mobility.

The elements were then assembled inside the box, and precisely-located holes drilled in the base, to allow free passage for the dowel rods, which had been secured to the base of each element. Aluminium collars with suitable tightening screws were then positioned underneath

PLATE 5



(B)



(A)

the laminated base, in order to regulate the vertical movement of the individual elements. In each case, an appropriate scale was marked off on each rod at intervals of $1/10$ of an inch, with numerical markings at every inch.

To complete the process of construction, a suitable plywood top was provided, and each element was painted a neutral grey, in order to obtain the maximum degree of contrast during photography.

APPENDIX B - The nature of tuberculosis

The tubercle bacillus discovered by Koch in 1882 is a rod-shaped organism varying from 1. to 4. μ in length, and from 0.3 to 0.6 μ in breadth. In comparison with other micro-organisms, it is particularly slothful, being approximately 20 times slower during growth, and producing only two new generations in a day. The bacillus ceases to grow at temperatures less than 45°F, and has an optimum growth temperature of 100.4°F. As a parasite it has no sustained life outside the body of the host, although by virtue of its remarkable resilience, it can survive in dust for considerable periods. (Hewitt & Stewart 1951: 215, Gloyne 1944:22) Essentially there are four distinctive forms of the bacillus - viz. a) human, b) bovine, c) avian, and d) strains associated with cold-blooded animals. These various types are not, however, mutually exclusive. That is to say, the human variety of the bacillus can promote tuberculous lesions in a large number of other animals, whilst the bovine strain can produce similar lesions in man himself. However, in general the amount of natural transgression is limited: bovine bacillus accounting for no more than 1% of all human cases of tuberculosis (W.G. Savage 1929).

Transmission from one individual to another appears to be effected in the main by droplet infection, although the possibility of infection by inhalation of dust particles containing the bacillus need not necessarily be discounted. The subsequent entry of the infection into the body of the victim takes place by one of four routes - viz. a) the respiratory tract b) the digestive tract c) the skin or d) the genito-urinary tract. However, since the most common form of the disease has the lungs as its 'nidus', (i.e. phthisis) the respiratory tract appears to be the most frequent route of infection.

Once inside the body, the bacillus attaches itself to a particular tissue - e.g. in the lung - and produces a lesion or nodule of tubercles, which is referred to as the 'primary focus'. If the body is unable to combat this initial encroachment, the bacillus spreads out to secondary foci, which in turn disseminate the infection to additional satellite foci (Gloyne 1944:60).

Eventually, each individual focus becomes septic, and produces a poison which gradually passes into the blood stream. It is this process of poisoning and resultant fever which finally causes the death of the victim. (Bridge 1903:32)

Considering the remarkable uniformity in the virulence of the bacillus, both in time and space, it is quite remarkable how tuberculosis of the lung (phthisis) is such a variable disease, in both its resultant effect upon an individual and its clinical course. Indeed, whereas one particular individual may experience sustained periods of intimate contact with a known infective case, and apparently fail to contract even a mild clinical manifestation of the disease; another subject may be reduced quite rapidly to a terminal tuberculous state as a result of a relatively brief period of exposure. Nevertheless, it must be remembered that most individuals in a particular community eventually succumb to primary infection by the tubercle bacillus, although, of course, the vast majority of these cases do not progress beyond this initial stage. In fact, the work of Dahlberg concerned with the incidence of tuberculosis in Sweden seemed to indicate that up to 95% of the population sooner or later became tuberculin positive, although "under the social conditions existent in Sweden this occurs in many cases well on into adult life." (Dahlberg 1949:222) Similar conclusions were reached by Naegeli, working in Switzerland, who observed that in a sampled population 71% had been previously infected.

The age-specific regime of tuberculosis mortality is characterised by a double maxima, consisting of an initial rise during early infancy, followed by a more significant peak during adult life. The period of least infection and mortality for both sexes is during the latter stages of school attendance, when a temporary state of relative equilibrium is reached. In the case of the adult maximum, peak incidence occurs during the 15-24 age group for females, as opposed to the 55-64 age group in the case of males (Jessop 1955:75). This apparent anomaly has been explained in terms of basic physiological differences, as well as differences in working conditions. As Dahlberg comments, "One gains the impression that puberty plays a decisive part in the fact that women have a more rapid rise of the death rate. Whether or not hormonal readjustment taking place at this time makes any difference, or whether the causative factor underlying the increase is the beginning of work, it is at present impossible to decide." (Dahlberg 1949:224)

As may be seen from tables 1 and 2, there is also a considerable differentiation between the sexes in terms of total incidence of phthisis. Indeed, the absolute number of deaths from the disease in County Durham for the period 1963-6 was on average 4.7 times higher for males than for females: a figure which, if expressed as a sex-specific ratio, is increased to 4.92.

TABLE 1. - Respiratory T.B. Mortality in Co. Durham, 1963-66.

A R E A	MALES	FEMALES	RATIO (M / F)
County Boroughs	124	30	4.1
Urban Districts	143	27	5.3
Rural Districts	78	16	4.9

TABLE 2. - Respiratory T.B. Notifications in Co. Durham, 1963-66.

A R E A	MALES	FEMALES	RATIO
Felling U.D. } Hebburn U.D. } Jarrow N.B. }	276	164	1.6
Sunderland C.B.	249	153	1.6

As far as the notification of new cases is concerned, the sex difference is not quite so dramatic, although there is still a significant excess of male notifications.

Collis (1923) observed that the industrialisation of a particular community had a profound effect upon the levels of phthisis mortality, as well as promoting changes in the age distribution of cases. With the onset of industrialisation, the peak incidence for both males and females tended to occur in early adult life, associated in all probability with the overcrowded working conditions, as a result of the initiation of factory employment. "The inroads of the tubercle bacillus on the world of men migrating from green fields to murky town can be readily imagined." (Gloyne 1944:98) However, as society became more adjusted to the industrial age, and both living and working conditions improved, in response to the rise in real earnings, the period of peak incidence, at least for males, reverted gradually to late adult life.

Stocks and Karn (1931:350) discovered that although the phthisis mortality rate for England and Wales had been declining quite rapidly from the late nineteenth century onwards, the geographical variability of the disease remained surprisingly high. For England and Wales, the standard deviation of tuberculosis mortality rates calculated by county was found to be over two times the value for cancer mortality. This

considerable spatial variability displayed by phthisis strongly supports the general hypothesis that the incidence of tuberculosis is primarily determined by the interaction of particular environmental factors, rather than by purely hereditary factors.

APPENDIX C - Previous work on the causation
of tuberculosis

Dr. John Snow, over one hundred years ago, commented that, "the causes of phthisis are involved in great obscurity...", (Snow, 1855:24) although "it is most likely that the mortality at every period of life is influenced more by the habits, occupations and pecuniary circumstances of the people than by any other causes." (Snow 1855:21) Despite the great advances in both medicine and social hygiene that have taken place since the last century, the controversy between hereditary and environmental causation still continues; and the role of particular environmental factors is still very much a matter of conjecture.

a) Heredity or environment?

The work of Wright and Lewis (1921), and Lurie (1941) concerned with guinea pigs and rabbits respectively, appeared to prove that it was possible to produce differing degrees of resistance to tuberculosis infection, by selective breeding; although these differences were nullified under conditions of high dosage of infection. These findings appeared to lend support to the work of Pearson (1907), who discovered that, whereas in the case of both parents (human) being tuberculosis over 57% of the offspring contracted a clinical form of the disease; only 29% of the offspring became overtly tuberculous where only one parent was a known case. However, as Anderson comments, this apparently significant difference could merely reflect inherent differences in living conditions (conducive to tuberculosis) between the two types of household, and thus "we lack definite evidence that a hereditary factor plays a predominant part in the development to tuberculosis in humans." (Anderson et alia, 1957:2).

A preoccupation with the most obvious lines of infection (i.e. intra-familial) has inevitably led to the considerable overstressing of hereditary factors in the causation of the disease. Indeed as Laidlaw (1949) noted in Glasgow, of 2,829 cases of pulmonary tuberculosis notified in 1949, only 509, or 18%, had ever lived in the same household as a known tuberculosis case. Consequently, it may be more appropriate to regard heredity as merely a predisposing factor, which renders particular individuals susceptible to infection, and which is subsequently modified through the action of environmental conditions (Gloyne 1944:28; Dubos & Dubos 1953:115).

b) Environmental factors

As has already been mentioned above, in such a complex web of causation, it is exceptionally difficult to isolate elements from the network. Nevertheless, for ease of comprehension, the major results and conclusions concerning each of the important causal factors have been collated below under separate headings.

i) Overcrowding.

Bradbury noted that in Tyneside "overcrowding was indictable beyond reasonable doubt as a factor of definite importance." (Bradbury 1933:18) This observation was subsequently supported by the work of Anderson et alia (1957:2) and Stein (1952:9) who found that "the most consistent and largest associations of tuberculosis mortality were those with ordinary overcrowding". On the other hand, D'Arcy Hart and Wright criticised the overcrowding index as too arbitrary and being located too near the worst extreme of the density scale, and suggested that housing density was a more appropriate factor, since, "in a droplet-borne disease such as phthisis, closeness of personal contact between all members of the community is a more relevant consideration." (D'Arcy Hart and Wright 1939:119)

More recently, the findings of Hewitt and Stewart (1951:222) derived from an investigation of the incidence of tuberculosis in the Northampton boot and shoe industry appeared to indicate that "although there is a definite association between risk of tuberculosis and numbers of persons working together, there is no perceptible association between risk of tuberculosis and over-crowding."

ii) Urbanisation.

As early as 1856 Johnston noted that "It (consumption) is uniformly more fatal in cities than in the country: in England the excess in cities is equal to 25%." (Johnston 1856:62) This significant difference (at least in the case of males) Snow attributed solely to "indoor employments... as contrasted with the exercises in the open air of the country." (Snow 1855:24)

Almost one hundred years later, Dahlberg recognised a similar association between urbanisation and tuberculosis, in quite a number of European countries. However, he concluded that since a substantial sex differential was involved, the causal factor was not in fact urbanisation itself, but another closely related variable (Dahlberg 1949). Nevertheless, McDonald (1952:263) still considered that "Frequent close contact with many people over long periods seems to be the most likely factor, and presumably acts by increasing the risk of exposure to infection and reinfection."

Terris (1948), on the other hand, proposed the hypothesis that the excess of tuberculosis mortality in urban areas was due to the increased tension and overstrain incurred by particular individuals in an effort to adjust to the changing urban environment. As Bridge (1903:73) comments, "Mental worry and discouragement lower vitality and so invite the disease ... Overstimulation (also) plays a part in causation. In

our intense lives we can hardly avoid overstimulating in some direction, at some time." However, this hypothesis was subsequently questioned by the findings of Dubos and Dubos, who noted that the urban areas of the country were in fact experiencing the most marked decreases in both notification and mortality rates for tuberculosis.

iii) Race.

Race, as a distinct causal factor in tuberculosis, is only rarely mentioned in standard texts on the disease, and only in two out of some 70 references consulted was the topic considered in any detail. Springett et alia (1958:140) in studies of immigrants in the Birmingham area, discovered that the disease was twice as prevalent amongst Irish-born, and five times as prevalent amongst Asian-born immigrants, as amongst the indigenous population. The explanation of the former was given as the arrival of uninfected young adults into considerably more infectious circumstances. On the other hand, the high prevalence amongst the latter was most probably due to the immigration of considerable numbers of Asians already having the initial stages of the disease. In support of these observations, Bradbury also noted a substantial excess of tuberculosis amongst the Irish families of Tyneside, and in particular at Jarrow. (Bradbury 1933:58)

iv) Occupation.

Quite apart from the factors of urban employment and overcrowding due to the initiation of factory working, there still appear to be a distinct group of occupational hazards which have been invoked as factors in the causation of tuberculosis. One such hazard is dust; varieties of which are associated with industries such as coalmining (Collis 1924, D'Arcy Hart et alia 1942), glass working (Sutherland 1923) and printing, all of which display particularly high prevalence rates for phthisis.

"It is possible that a dust may light up an antecedent smouldering tuberculosis, but it is more probable that in most cases the tubercule bacillus has become implanted upon an already existing dust fibrosis."

(Gloyne 1944:102)

v) Social class.

Unfortunately in the United Kingdom and Northern Ireland investigation into the relationship between social class and tuberculosis can only take into consideration the male population, since appropriate data, relating married women to the occupations of their husbands, have not yet been collated. Nevertheless, Merrett, in his study in Northern Ireland between 1949 and 1953, succeeded in discerning important differences between the social classes in respect of mortality from respiratory tuberculosis. Rather surprisingly, social class IV (semi-skilled) had a comparable mortality rate to classes I and II combined (professional and intermediate respectively). On the other hand, class III (skilled) experienced approximately double this rate; whilst class V (unskilled) had twice the rate for class III (Merrett 1959:160). Similar results were obtained by Benjamin (1953) in London, who noted a close association between the proportion of the population in social class V and the level of tuberculosis mortality.

However, it must be remembered that this type of differential is subject to the limitations of the initial definitions of social class used, and as such it must be regarded only as an approximate indication of the true situation.

vi) Housing.

Poor housing, as a predisposing factor in the transmission of tuberculosis, has been invoked by a number of workers, despite the inherent difficulty of objective definition. Prominent amongst these

workers was Stein, who concluded from her work in Glasgow that "...housing conditions form the largest single factor in the 'complex' (of causation)." (Stein 1952:2) In addition, Bradbury, working in Tyneside, noted a far greater concentration of tuberculous families in areas of sub-standard or 'insanitary' dwellings than would have been expected due to accidents and errors of sampling. (Bradbury 1933:48)

vii) Nutrition.

Although this factor is suggested as a possible causative factor by many writers (e.g. Snow 1855, D'Arcy Hart & Wright 1939, and Stein 1953), it is rarely considered in any detail. This is again probably due to the difficulties associated with the initial definition of indices and the collecting of the relevant data.

Bradbury (1933) observed that in Jarrow and Blaydon there was a substantially greater incidence of undernourishment amongst tuberculous families in comparison to those which were apparently free from tuberculosis. Moreover, in an analysis of the undernourished families it was discovered that 21.1% were free from sickness; 29.6% had sickness other than tuberculosis; and 43.7% were tuberculous. This suggested that undernutrition was not merely a predisposing factor for disease in general, but was of particular relevance to the causation of tuberculosis. Indeed of the three hypotheses capable of explaining the apparent association, only one "that undernutrition causes tuberculosis" (p.39) was deemed to be consistent with the observed facts. In particular, the shortage of fresh milk in the diet, and the subsequent substitution of condensed milk, was regarded by Bradbury "as being more important than shortage of the other food-stuffs studied in predisposing to tuberculosis in an urban population." (p.41)

An investigation by Orr and Gilks (1931) into the health of two African tribes also supported the theory of nutritional causation. It

was shown that the incidence of phthisis was many times greater amongst the predominantly vegetarian Akikuyu than among the meat-eating Masai.

viii) Poverty.

Like nutrition and housing, this particular factor is difficult to define objectively; except of course in terms of real income, which is in itself a rather unsatisfactory measure. Thus once again one is forced to consider rather indirect expressions of poverty in relation to the causation of tuberculosis. However, Bradbury (1933:59) was convinced that "it is not the mere abstract state of poverty which causes tuberculosis, but rather the consequences or accompaniments of poverty." Indeed many of these 'consequences' have already been considered - viz. overcrowding, housing, nutrition and socio-economic class, etc. - although the measure of influence that poverty exerts through each individual factor is as yet unknown.

ix) Physical factors of the environment.

Originally, the physical environment was deemed to have a significant effect in causation. Johnston (1856), for example, in an analysis of military mortality tables concluded that "Consumption is more prevalent in tropical than in temperate countries." Moreover, in support of the hypothesis that the incidence of the disease decreased with falling temperature, he quoted the work of Fuchs (1853), which seemingly indicated "That in Northern Europe, it is most prevalent at the level of the sea, and that it decreases with increase of elevation to a certain point. At Marseilles, on the other hand, the mortality from this cause is 25%; at Oldenburg 80 feet above the sea, it is 30%; at Hamburg, 48 feet above the sea, it is 23%; while at Eschwege, 496 feet above the sea, it is only 12%; and at Brotterode, 1,800 feet above the sea, 0.9%".

(Johnston 1856:61)

However, by the turn of the century, the role of social and economic factors, together with hereditary consideration, was unquestioned; so much so that Bridge (1903:75) declared that "climate exercises little or no protective influence over the individual against the acquisition of tuberculosis."

Nevertheless it is perhaps unwise at this stage to discount altogether the possible influences that particular elements of the physical environment may be exerting on the incidence and mortality rates of tuberculosis. This is particularly relevant in the case of air pollution, where significant causal relationships have been proved to exist between this factor and the prevalence of many respiratory disorders, including respiratory tuberculosis (see in particular Daly, 1959; Fairburn and Reid, 1958; Laidlaw, 1960; Pemberton and Goldberg, 1954). In particular the results of Daly are extremely significant. In a study of the 83 County Boroughs of England and Wales, he discovered that after Bronchitis and pneumonia, phthisis exhibited the highest degree of association between respiratory diseases and domestic air pollution (Daly 1959:16).



DEPENDENT VARIABLE - NOTIFICATION RATES FOR RESP. TUBERCULOSIS, 1961-65

INDEPENDENT VARIABLES - 1. DENSITY PER ACRE
2. SOCIO-ECONOMIC GROUP 3
3. SOCIO-ECONOMIC GROUP 5

INTERCORRELATIONS OF INDEPENDENT VARIABLES WITH DEPENDENT VARIABLES
RY(1)= 6.89651E-01 RY(2)= 6.20828E-01 RY(3)= 5.75301E-01E

REGRESSION COEFFICIENTS

BM(1)= 8.94907E-02 BM(2)= 8.07820E-02 BM(3)= 1.39840E-01E

STANDARD DEVIATIONS OF REGRESSION

SB(1)= 5.16549E-02 SB(2)= 2.87377E-02 SB(3)= 8.44011E-02E

COEFFICIENTS

STUDENT T VALUES

TT(1)= 1.73247E+00 TT(2)= 2.81100E+00 TT(3)= 1.65685E+00E

INTERCEPT =	-16.023
MULTIPLE CORR. COEFF.	0.765
STAND. ERROR OF ESTIMATE	12.987
SUMS OF SQUARES	
ATTRIB. TO REGRE.	8541.262
DEGREES OF FREEDOM	
ASSOC WITH SSAR.	3.000
MEAN SQUARE OF SSAR	2847.087
SUMS OF SQUARES OF DEV.	
FROM REGRESSION SSOR	6071.785
DEGREES OF FREEDOM	
ASSOC. WITH SSAR	36.000
MEAN SQUARE OF SSOR	168.661
F VALUE	16.881

ESTIMATED NOTIFICATIONS FOR RESP. TUBERCULOSIS, 1961-65 CALCULATED BY MULTIPLE REGRESSION

DEV(1)= 4.74968E+01	DEV(2)= 6.02926E+01	DEV(3)= 8.28153E+01	DEV(4)= 5.83225E+01	DEV(5)= 5.17160E+01
DEV(6)= 2.84668E+01	DEV(7)= 3.74412E+01	DEV(8)= 3.33421E+01	DEV(9)= 3.77259E+01	DEV(10)= 2.26793E+01
DEV(11)= 2.56009E+01	DEV(12)= 3.43552E+01	DEV(13)= 4.18947E+01	DEV(14)= 2.71964E+01	DEV(15)= 2.16639E+01
DEV(16)= 5.09854E+01	DEV(17)= 5.77640E+01	DEV(18)= 5.92053E+01	DEV(19)= 2.71355E+01	DEV(20)= 3.74794E+01
DEV(21)= 5.87475E+01	DEV(22)= 2.85935E+01	DEV(23)= 4.03426E+01	DEV(24)= 3.78248E+01	DEV(25)= 2.91796E+01
DEV(26)= 3.62280E+01	DEV(27)= 4.82923E+01	DEV(28)= 2.81409E+01	DEV(29)= 3.85732E+01	DEV(30)= 3.49771E+01
DEV(31)= 1.63087E+01	DEV(32)= 2.95808E+01	DEV(33)= 1.73912E+01	DEV(34)= 1.97523E+01	DEV(35)= 2.55247E+01
DEV(36)= 2.51532E+01	DEV(37)= 2.09180E+01	DEV(38)= 1.75700E+01	DEV(39)= 3.49444E+01	DEV(40)= 2.21564E+01E

REGRESSION RESIDUALS

Z(1)=-1.04968E+01	Z(2)= 1.77073E+01	Z(3)=-7.81536E+00	Z(4)=-7.32255E+00	Z(5)=-2.47160E+01
Z(6)=-8.46688E+00	Z(7)=-1.64412E+01	Z(8)= 6.65788E+00	Z(9)=-1.72596E+00	Z(10)= 1.53706E+01
Z(11)=-1.60092E+00	Z(12)= 9.64477E+00	Z(13)= 1.05270E-01	Z(14)=-6.19645E+00	Z(15)= 7.33607E+00
Z(16)= 2.20145E+01	Z(17)=-2.17640E+01	Z(18)= 2.97946E+01	Z(19)=-7.13552E+00	Z(20)=-3.49794E+00
Z(21)= 2.32524E+01	Z(22)= 7.40640E+00	Z(23)=-1.13426E+01	Z(24)=-1.18248E+01	Z(25)=-1.11796E+01
Z(26)=-2.28027E-01	Z(27)=-1.12923E+01	Z(28)=-2.11409E+01	Z(29)= 3.42678E+00	Z(30)= 3.32288E+00
Z(31)=-3.30879E+00	Z(32)= 3.41914E+00	Z(33)= 4.60879E+00	Z(34)= 7.24768E+00	Z(35)= 4.47528E+00
Z(36)=-6.15328E+00	Z(37)= 1.08198E+00	Z(38)=-2.57008E+00	Z(39)= 1.30555E+01	Z(40)= 1.28435E+01E

MUREGR & PROC OPTIONS (MAIN) &

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STMT LEVEL NEST
1 1 MUREGR & PROC OPTIONS (MAIN) &
2 1 DATA ENTRY &
3 1 BEGIN DCL (Q,P) FIXED BINE
4 2 GET LIST (Q,P) &
5 2 M = 0 &
6 2 ABOVE &
7 2 GET LIST (NDEP) &
8 2 GET LIST (K) &
9 2 BEGIN &
10 3 DCL X(Q,P) &
11 3 DCL (R,RX)(Q), (XBAR,STD,B,D,T)(Q) &
12 3 DCL (ISAVE(K>1)) &
13 3 DCL (RTR(K>1)) &
14 3 DCL (Z)(P) &
15 3 DCL (RY)(K) &
16 3 DCL (DEVI)(P) &
17 3 DCL (BB)(K) &
18 3 DCL (DD) &
19 3 DCL (ANS(Q) CHAR(70)) &
20 3 DCL (BMSB,TT)(K), ANS(10) &
21 3 DO I = 1 TO K GET LIST(ISAVE(I)) & ENDE
22 3 IF M = 99 THEN GOTO BELOW
23 3 DO I = 1 TO Q &
24 3 DO I = 1 TO Q &
25 3 GET LIST(LABS(I)) &
26 3 DO I = 1 TO P &
27 3 GET LIST(X(I,I)) &
28 3 ENDE ENDE
29 3 BELOW &
30 3
31 3
32 3
33 3 CALL CORREL(Q,10,4(1,1),XBAR(1),STD(1),RX(1,1),R(1,1),B(1),D(1),T(1)) &
34 3 IF M = 99 THEN GOTO MISSE &
35 3 PUT PAGES &
36 3 PUT EDIT('MULTIPLE CORRELATION COMPUTATION-')(A,X(3)) &
37 3 PUT SKIP(2) EDIT('MEAN AND STANDARD DEVIATION OF VARIABLES')(A) &
38 3 DO I = 1 TO Q &
39 3 PUT SKIP EDIT('MEAN = ',XBAR(I),'STANDARD DEVIATION = ',
40 3 STD(I)) F(4,0),
41 3 X(3),A,X(2),F(7,3),X(2),A,F(8,3)) & ENDE
42 3 FROM MEANS'(A) &
43 3 PUT SKIP(2) DATA(RX) &
44 3 PUT SKIP(2) EDIT('MATRIX CONTAINING CORRELATION COEFFICIENTS')(A) &
45 3 PUT SKIP(2) DATA(B) &
46 3 PUT SKIP(3) EDIT('DIAGONAL OF THE MATRIX OF SUMS OF CROSS-PRODUCTS
OF DEVIATIONS FROM MEAN')(A) &
47 3 PUT SKIP(2) DATA(B) &
48 3 MISSE &
49 3 CALL ORDER (Q,R(1,1),NDEP,K,ISAVE(1),RK(1,1),RY(1)) &
50 3 CALL MINV(RK(1,1),K,DD,BM(1),S(1)) &
51 3 CALL MULT(P,K,XBAR(1),STD(1),B(1),RK(1,1),RY(1),ISAVE(1),BM(1),
S(1),TT(1),ANS(1)) &
52 3 PUT PAGE &
53 3 PUT SKIP(2) DATA(LABS(NDEP)) &
54 3 PUT SKIP(2) &
55 3 DO I = 1 TO K &
56 3 PUT SKIP LIST(LABS(ISAVE(I))) & ENDE

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STMT LEVEL NEST

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57 3 PUT SKIP(4) EDIT('INTERCORRELATIONS OF INDEPENDENT VARIABLE'S WITH
DEPENDENT VARIABLE'S')(A) &
58 3 PUT SKIP(1) DATA(RY) &
59 3 PUT SKIP(4) EDIT('REGRESSION COEFFICIENTS')(A) &
60 3 PUT SKIP(2) DATA(BM) &
61 3 PUT SKIP(4) EDIT('STANDARD DEVIATIONS OF REGRESSION
COEFFICIENTS')(A) &
62 3 PUT SKIP(2) DATA(SB) &
63 3 PUT SKIP(5) EDIT('STUDENT T VALUES')(A) &
64 3 PUT SKIP(5) DATA(TT) &
65 3 PUT SKIP(5) EDIT('INTERCEPT = ',ANS(1),'MULTIPLE CORR. COEFF.',
PUT SKIP(5) EDIT('ESTIMATE',ANS(3),'SUMS OF SQUARES',
ANS(2),'STAND. ERROR OF ESTIMATE',ANS(4),'DEGREES OF FREEDOM',ASSOC WITH SSAR,'
ATTRIB. TO REGRE.',ANS(4),'DEGREES OF FREEDOM',SUMS OF SQUARES OF DEV.',
ANS(5),'MEAN SQUARE OF SSAR,ANS(6),'DEGREES OF FREEDOM',
'FROM REGRESSION SSOR',ANS(7),'MEAN SQUARE OF SSAR,ANS(9),'F VALUE ',
ANS(10)) SKIP,A,COLUMN(30),F(18,3),
SKIP,A,COLUMN(30),F(18,3),
SKIP,A,COLUMN(30),F(18,3),
SKIP,A,SKIP,A,COLUMN(30),F(18,3),
SKIP,A,SKIP,A,COLUMN(30),F(18,3),
SKIP,A,COLUMN(30),F(18,3),
SKIP,A,SKIP,A,COLUMN(30),F(18,3),
SKIP,A,COLUMN(30),F(18,3),
SKIP,A,COLUMN(30),F(18,3)) &
66 3 DO I = 1 TO P &
67 3 DEV(I) = ANS(I) &
68 3 DO I = 1 TO K &
69 3 DEV(I) = DEV(I) + BM(I)*X(ISAVE(I)),I &
70 3 ENDE ENDE
71 3 PUT SKIP(2) DATA(DEV) &
72 3 DO J = 1 TO P &
73 3 Z(J) = (X(1,J) - DEV(J)) &
74 3 ENDE
75 3 PUT SKIP(2) DATA(Z) &
76 3 GET LIST(M) &
77 3 PUT SKIP LIST(M) &
78 3 IF M > 12 THEN GOTO ABOVE &
79 3 ENDE MUREGR &
80 3
81 3

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SMKS PROC OPTIONS(MAIN1)

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STMT LEVEL NEST
1 1 SMKS PROC OPTIONS(MAIN1)
2 1 DCL (POPEN(1:2),2&12),POP(1:2,1&4,2&12),CHECK(1:13),ADD(2:1:2)
  FIXED BIN(31)
4 1 DCL DISTO(2) FIXED BIN(31)
4 1 DCL RATIO(1:2,1&4)
5 1 DCL (MEAN(2)) FLDAT DECS
6 1 DCL (YEAR,SEXY,LA,CODE,MOCDS,M,JJ,J,1:1) FIXED BINE
7 1 DCL SEX(1:2) CHAR(10) DCL JUNK CHAR(1)
10 1 DCL DEATH CHAR(30)
11 1 DCL IMAGE FILE STREAM INPUT
12 1 GET LIST(N,DEATH)
13 1 GET LIST(POP,POPEN)
14 1 ABOVE =
15 1 DISTO = 0
16 1 IF N = 30 & N = 13 THEN DO & L = 2 & ENDE
20 1 GET LIST(H)
21 1 DO I = 1 TO 40
22 1 DO J = 1 TO 2
23 1 ADD = 0
24 1 DO JJJ = 1 TO 5
25 1 GET FILE(IMAGE) EDIT(CHECK(+),JUNK(1:5) F(5),1:5)
26 1 DO J = 1 TO MOCDS
27 1 GET FILE(IMAGE) EDIT(CHECK(+),JUNK(1:3) F(5),A(1:5))
28 1 IF CHECK(1) = N THEN DO
30 1 DISTO(1) = DISTO(1) + CHECK(2)
31 1 DO JJJ=3 TO 12
32 1 ADD(JJJ) = ADD(JJJ)+CHECK(JJJ)
33 1 ENDE
34 1 ENDE
35 1 ENDE
36 1 ENDE
37 1 IF L = 2 THEN DO & GOTO BEL ENDE
41 1 X = DISTO(1)*1000
42 1 Y = POPEN(1,2)*5
43 1 Z = (X/Y)*100
44 1 MEAN(1) = ZE
45 1 X = DISTO(2)*1000
46 1 Y = POPEN(2,2)*5
47 1 Z = (X/Y)*100
48 1 MEAN(2) = ZE
49 1 DO J=3 TO 12
50 1 IF I=4 THEN DO
52 1 X = (ADD(J) * 2400)
53 1 Y = (POP(1,1),J) * 0.1231
54 1 CR(J) = X/Y
55 1 GOTO BELOW
56 1 ENDE
57 1 IF I = 5 THEN DO
59 1 X = (ADD(J) * 12000)
60 1 Y = (POP(1,1),J) * 0.621
61 1 CR(J) = X/Y
62 1 GOTO BELOW
63 1 ENDE
64 1 IF I = 17 & I = 39 THEN DO

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STMT LEVEL NEST
66 1 4 X = (ADD(J) * 4000)
67 1 4 Y = (POP(1,1),J) * 0.171
68 1 4 CR(J) = X/Y
69 1 4 GOTO BELOW ENDE
71 1 3 X = (ADD(J)*10000) Y = (POP(1,1),J)*51 CR(J) = X/Y
74 1 3 BELOW PRD(J) = CR(J)*POPEN(1,J)
75 1 3 ENDE
76 1 2 SIMA = SUM(PROD)
77 1 2 SMR(1,1) = SIMA / POPEN(1,2)
78 1 2 BEL
79 1 ENDE
80 1 CLOSE FILE(IMAGE)
81 1 DO I = 1 TO 2
83 1 RATIO(1,1) = (SMR(1,1)*100)/MEAN(1)
84 1 ENDE ENDE
86 1 SEX(1) = 'MALES' SEX(2) = 'FEMALES'
88 1 DO I = 1 TO 2
89 1 PUT PAGE
90 1 PUT SKIP(2) EDIT('STANDARD MORTALITY RATES PER 100,000 F.R.',SEX(1),
  ' FOR ',DEATH)(A,A,A)
91 1 PUT SKIP(3) LOCAL AUTHORITY STAND. MORT. RATE
92 1 PUT LIST(' LOCAL AUTHORITY STAND. MORT. RATE')
93 1 PUT LIST(' MORTALITY RATIO')
94 1 PUT SKIP
95 1 DO I = 1 TO 40
96 1 PUT SKIP EDIT(1,SMR(1,1))(COLUMN(11),F(3),COLUMN(28),F(1,3))
97 1 PUT EDIT(RATIO(1,1))(X(16),F(7,2))
98 1 ENDE
99 1 PUT SKIP(3) EDIT('MORT-RATE FOR COUNTY DURHAM = ',MEAN(1))(A,F(7,2))
100 1 ENDE
101 1 GET LIST(N,DEATH)
102 1 OPEN FILE(IMAGE) INPUT
103 1 GOTO ABOVE
104 1 END SMRS

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