THE ECONOMIC AND SOCIAL IMPACT OF HUMAN SALMONELLOSIS IN ENGLAND AND WALES

A study of the costs and epidemiology of illness
and the benefits of prevention

by

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ABSTRACT

This thesis presents a detailed analysis of illness related costs of human salmonellosis in England and Wales, estimated at £263 million (minimum), including intangible costs, in 1988, and explores potential benefits of preventive activities aimed at the poultry industry.

To explore trends in reported infection and the factors which may influence those trends, salmonella reporting between 1960 and 1989 was examined. Trends in foodborne illness were associated with increased reporting of salmonella infection. The factors which contributed to this increase included intrinsic factors such as the microbiological quality of food, and extrinsic factors such as ambient temperature which may amplify intrinsic effects. Evidence that poultry products were important vehicles of human illness was supported by trends in infections in animals and poultry, and food consumption patterns. Thus a significant decrease in human infection would result from reduction in poultry contamination.

The findings of a unique and detailed survey of 1,482 human salmonella cases, presented in this thesis, indicated tangible costs of illness of £996,350 to £1,091,131. Over a third (£392,822 - £426,887) were costs related to investigation and treatment of cases and over half (£507,555 -£559,401) was production loss associated with sickness related absence from work. The remaining costs identified represented important costs to affected individuals and their families. Additional intangible costs of £1.57 million to £5.07 million were ascribed to value of lives lost and to pain and suffering estimates.

Extrapolation of costs, utilizing an index of severity developed for this study and categorisation of cases by level of treatment demanded, indicated national, tangible, costs of £231 million to £331 million; additional intangible costs were £32 million to £119 million). The cost-effectiveness of limiting these totals was explored by two approaches. Cost reduction by changes in cases management (eg. reducing faecal specimens tested and time off work) indicated small potential savings. However, substantial benefits were indicated by cost-benefit analysis of preventive activities including irradiation of poultry carcasses and use of competitive exclusion methods in poultry rearing.

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ABBREVIATIONS

A&E	Accident and Emergency Department
BMA	British Medical Association
BSE	Bovine Spongiform Encephalopathy
CsCDC	Consultants in Communicable Disease Control
CDSC	Communicable Disease Surveillance Centre
CDR	Communicable Disease Report
CE	Competitive Exclusion
CEHO	Chief Environmental Health Officer
CSF	Cerebrospinal fluid
DEP	Department of Enteric Pathogens (now Laboratory of Enteric Pathogens, LEP)
DES	Department of Education and Science
DHSS	Department of Health and Social Security (see DoH)
DoE	Department of Employment
DoH	Department of Health (previously DHSS)
DM	Deutschmark
DT	Definitive Type (phage types of **Salmonella typhimurium**)
DoT	Department of Transport
EAPS	Economic analysis of preventive strategies
EC	European Community
EHD	Environmental Health Department(s)
EHO	Environmental Health Officer(s)
FDA	Food and Drug Administration (United States)
FRG	Federal Republic of Germany
GLIM	Generalised Linear Interactive Modelling
GNP	Gross National Product
GP	General Practitioner
HACCP	Hazard Analysis Critical Control Point
HC	Human capital (approach)
ICD	International Classification of Diseases
ISC	Indian sub-continent
LA	Local Authority (Authorities)
L&S	Landefeld and Seskin (approach)
MAFF	Ministry of Agriculture, Fisheries and Food
MLC	Meat and Livestock Commission

MMB	Milk Marketing Board
MOsEH	Medical Officer(s) for Environmental Health
MoT	Ministry of Transport
NAS	National Academy of Sciences (United States)
NHS	National Health Service
OP	Out Patients (Department)
OPCS	Office of Population Censuses and Surveys
PHLS	Public Health Laboratory Service
PHS	Public Health Significance
PMC	Pseudomembranous colitis
PT	Phage Type
TCE	Total Consumer Expenditure
UK	United Kingdom
USA	United States of America
VL	implicit Value of Life (approach)
WHO	World Health Organisation
WP	Willingness to pay (approach)
$	United States dollars
Can$	Canadian dollars

DEFINITIONS OF SOME COMMON TERMS ASSOCIATED WITH FOODBORNE DISEASE AND SALMONELLOSIS*

Case	A case of food poisoning is a symptomatic person from whom the relevant organism has been isolated, or who is part of an outbreak. In the Cost study all persons recruited into the survey are referred to as cases.
Sporadic case	A case with no known association with any other persons with similar illness or infected with the same organism.
Outbreak	Two or more related cases of food poisoning or salmonellosis.
Family outbreak	An outbreak affecting only the members of a single household.
General outbreak	An outbreak affecting the wider community.
Incident	Refers to a sporadic case or an outbreak. Therefore total incidents comprise all sporadic cases and all outbreaks.

These definitions are based on those given in the annual report: Food poisoning and salmonella surveillance in England and Wales:1982. British Medical Journal (1984); 288: 306-308.

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Chapter 1

SALMONELLOSIS AND OTHER FOODBORNE DISEASES: SOURCES OF INFORMATION AND TRENDS IN REPORTING

Introduction

Concern about increased recording of salmonellosis and other foodborne diseases and their recognition as a worldwide problem of major public health importance has been expressed for more than 20 years by the WHO and others (Steele, 1969; WHO, 1974, 1978; Hobbs, 1974; Waites and Arbuthnott, 1990). Where national statistics are available the trends in reported infection are generally upwards and there is increasing recognition that the socio-economic impact may be huge. Evidence suggests that much of this increase, at least in developed countries, is due to salmonella infection (Chapter 3). In terms of the increasing numbers of cases recorded annually, the number of isolations of salmonellas from humans has risen markedly from an average of about 5,000 a year in the 1960s (Galbraith, 1985, 1990; Galbraith et al, 1987a,b) to over 25,500 in 1989, and the potential economic impact of human and animal infection, salmonellosis is probably the most important foodborne illness in England and Wales.

This thesis therefore seeks to examine some of the factors which may have influenced reporting trends in England and Wales since 1960, to describe the economic and social consequences of salmonella infection and to model the potential cost-effectiveness of preventive and cost reducing activities. The two introductory chapters describe the human illness caused by salmonellosis, its treatment and the main sources of information which relate to the epidemiology of infection. The significance of salmonella infection in England and Wales and in other countries in the context of other foodborne diseases is discussed and the development of economic evaluation in the sphere of public health, particularly in relation to foodborne disease and salmonellosis, is reviewed.

Causes of foodborne illness

The WHO defines foodborne disease as "a disease of an infectious or toxic nature caused by, or thought to be caused by, the consumption of food or water" (WHO, 1981). The list of agents which may cause foodborne disease is a growing one and the agents of contemporary importance may change over time or from country to country. A classification and summary produced by the Centres for Disease Control in the USA in 1976 described over 200 agents (Bryan, 1976). The list included agents for which there was long-standing microbiological and epidemiological evidence of foodborne transmission, as well as diseases for which evidence is as yet inconclusive.

Bacteria are probably the most commonly reported agents of foodborne illness. They cause illness by three main mechanisms: toxin production in the food prior to consumption, toxin production in the human gut following ingestion of the organism, or by a more generalised or systemic infection. Other reported causes include: protozoa and other parasites; viruses and rickettsias; toxins in animals, which may be present naturally in the animal, may result from degradation of the animal flesh, or may be accumulated as a by-product of feeding; toxins in plants and fungi (mycotoxins); and chemical residues which accumulate in the food either because they occur naturally in high concentration or are pollutants of the environment, or are introduced into a food during its preparation (Hobbs and Roberts, 1987). There may be instances where no aetiological agent was found, either because the agent is difficult to identify, or a new agent was involved.

Food poisoning and salmonellosis in England and Wales since 1941

Two peaks in both statutory notifications and laboratory reported incidents of bacteriologically confirmed food poisoning have been recorded since 1941 (McCoy, 1975; Galbraith, 1985). The first occurred in the 1950s and the highest annual totals for notifications (12,719) and laboratory reported incidents (5,513) were recorded in 1955. This early peak was considered By McCoy (1975) and the analysis presented in this thesis (Chapter 3) concentrates on trends since 1960. There was a decline until 1966 (4,539 notifications, 3,743 incidents), since then numbers of notifications and laboratory reported incidents have risen steadily. Formal notifications in 1989 were 39,024, whilst the number of laboratory reported incidents was over 21,500 (see Chapter 3).

The observed trends in laboratory reported incidents were strongly influenced by the number of incidents of salmonella infection*; between 1969 and 1989 salmonellas accounted for 98% or more of incidents. Before 1969 the range was 51% to 96% of incidents (average 69%) (unpublished data). Incidents of unknown cause ranged between 1% and 47% over this period and may have reflected under diagnosis of salmonella incidents. If incidents of unknown cause were removed the proportion which were due to salmonellosis rose to ≥90%.

Although increased reporting may have been associated with factors such as improved laboratory and diagnostic procedures, increased interest in foodborne illness, improved investigation of incidents and improved reporting, evidence suggested the overall trends were real. Some of these factors are considered in Chapter 3.

For example, in the peak in the mid-1950s the high proportion of reports due to **S. typhimurium**, suggested the trend was real. Between 1950 and 1956 70% of reported incidents of salmonella infection were due to this one serotype. The subsequent fall in salmonella incidents followed a decline in reporting of **S. typhimurium** and reached its lowest total of 2,496 incidents in 1966. Thereafter numbers of incidents recorded have shown a steady rise and by 1986 had more than doubled the total of 1955. This second peak followed increased reporting of salmonellas other than **S. typhimurium**, and since 1988 trends were due to increased **S. enteritidis** infection, particularly **PT4** (Agriculture Committee, First Report, 1989; Report of the Committee on the Microbiological Safety of Food, 1990).

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*The name "salmonella" was first suggested by Lignieres in 1900 for a genus of gram negative non-sporing rods which are predominantly intestinal parasites of man and animals. The name is derived from that of an American veterinary surgeon, DA Salmon, who described the organism now called **Salmonella cholerae-suis** as the cause of hog cholera in 1884 (Ghysels, 1964). Since then over 2,000 different salmonellas (serotypes) have been identified.

Most of the approximately 2,000 known salmonella serotypes may cause gastrointestinal infection or colonisation of humans or animals. However, a small number of serotypes are adapted to specific hosts in which they usually cause septicaemic illness with relatively high morbidity and mortality and can produce a permanent carrier state in the host. Examples of these host-adapted types, which are less likely to cause illness in other animal species, are **S. typhi** and **S. paratyphi** in man; **S. dublin** in cattle; **S. cholerae-suis** in pigs; **S. pullorum** and **S. galinarum** in poultry and **S. abortus-ovis** in sheep.

Trends in salmonellosis in other developed countries

Increased reporting of salmonella infection in England and Wales is not unique. There was no identifiable trend in European countries reviewed by Greco and Schinaia (1988) for the period 1980 to 1985, however, data for six countries reviewed, Austria, Germany (FR), Poland, Sweden, Spain and France showed increases thereafter (Figure 1.1) (Gerigk, 1990; B Hubert, personal communication). However, trends in Poland, Spain and France may reflect improvements in surveillance. Similar increases were observed in a number of other European countries for which less complete data sets were available (Beckers, 1987; Gerigk, 1990; Hoogenboom, 1991, personal communication).

In Canada, incidents and cases of foodborne disease increased between 1980 and 1984; cases of salmonellosis increased over this period, but the number of incidents declined (Todd, 1990). An overall increase in foodborne illness was not evident in the USA. However, salmonella infection was the most common cause of illness of bacterial origin, and both the proportion of outbreaks which were due to salmonellas and the number of cases of salmonellosis increased from 1980 to 1987 (Chalker and Blaser, 1988; Bean et al, 1990; Bean and Griffin, 1990).

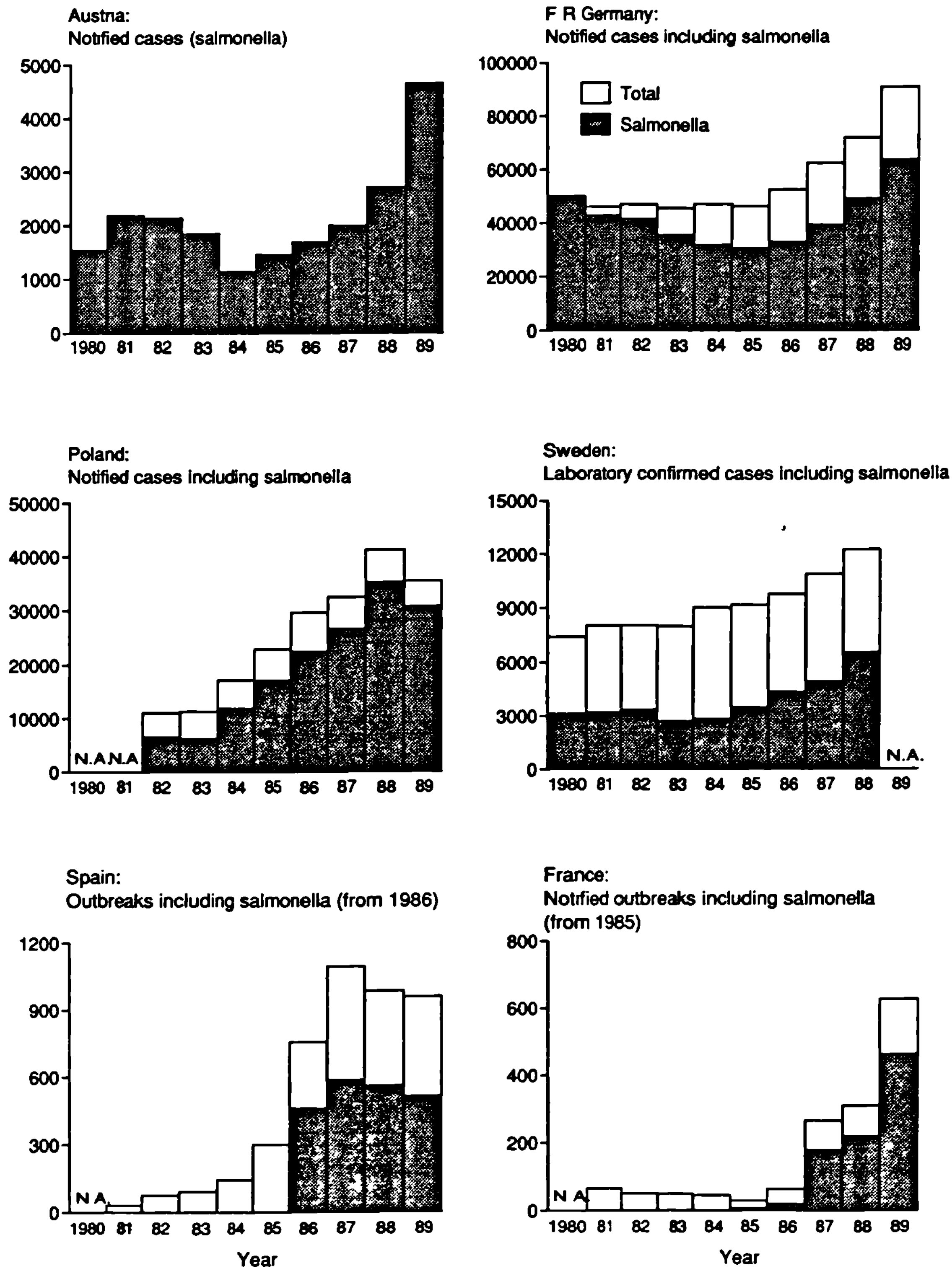
Increased salmonella infection recorded by many countries appeared to be associated with **S. enteritidis** although there were differences in the common strains; **PT 4** in England and Wales and western Europe, **PT 1** in eastern Europe, **PT 8** in Canada and **PTs 8** and **13a** in the USA (Anon, 1989; Khakhria et al, 1991; L Ward, Colindale, personal communication). Human salmonellosis should be largely preventable, and where measures have been taken to reduce contamination of a specific food, e.g. milk pasteurisation, this has been very effective in reducing human infections associated with that product (Sharp et al, 1985).

Human infection

Sources of infection

Infection in man usually results from ingestion of the organism in contaminated food followed by an incubation period, usually eight to 72 hours, during which the organism proliferates in the gut. Foods of animal origin are most frequently implicated as the sources of human

Foodborne disease statistics: selected European countries 1980-89



infection and meat was recognised by Gaertner as a source of human illness in 1888 (Ghysels, 1964). McCoy (1976) stated that "salmonellas have been isolated from all species of domesticated and wild animals and birds, and from reptiles." Domesticated species have been closely associated with human illness; the disease and sources of infection in animals is discussed in Appendix 1a (Anderson et al, 1961; Report,1964; Report, 1965; Lee, 1974; McCoy, 1975; Lyons et al, 1980; Anon, 1981c).

Less commonly other animals have been implicated as sources of human infection, and in the 1960s incidents of human illness were associated with pet meat (Galbraith et al, 1962; Beasley et al, 1967; Armentano et al, 1971; Penfold et al, 1979; Anon, 1981a; Chiodini and Sundberg, 1981). Occasionally vegetable products have been implicated as the source of illness, although, these were probably contaminated by human or animal faeces during processing (Galbraith et al, 1960; Anon, 1978a; O'Mahoney et al, 1990a). Nevertheless, the possibility of growth in these types of product, even in relatively acid conditions and from a low initial inoculum, cannot be ignored (Asplund and Nurmi, 1991).

More unusually, infection may be spread person to person, particularly in situations of high risk of faecal contamination of hands such as geriatric wards although such incidents appear to be infrequent even in the home (Thomas and Mogford, 1970; Ayliffe et al, 1979; Report of the PHLS Salmonella Sub-committee, 1980; Wilson et al, 1982; Tauxe et al, 1988; Joseph and Palmer, 1989). Rarely contaminated medical equipment such as endoscopes have spread infection (Ip et al, 1976; Beecham et al, 1979; O'Conner et al, 1982; McAllister et al, 1986). Despite the potential for spread by infected food handlers infection spread by this mechanism is reported only rarely (Pether and Scott, 1982; Buchwald and Blaser, 1984; Bush, 1985; Cruickshank, 1990; Hedberg et al, 1991).

Symptoms

Symptoms of salmonellosis may vary from mild to violent diarrhoea, abdominal pain and vomiting which are not usually severe, and fever which is common and accompanied by headache and chills. In cases of severe diarrhoea dehydration may lead to hypotension, cramps, oliguria and uraemia. The acute illness may last a few days and most patients normally recover within a week. Death is uncommon except in the very young or very old or debilitated. A small proportion of cases may develop bacteraemia or meningitis, or may develop localised infections causing abscesses, arthritis, cholecystitis, endocarditis, pericarditis, pneumonia, pyoderma or pyelonephritis (Report, 1985).

Some serotypes are highly invasive for man, eg. **S. typhi**, **S. paratyphi** and **S. cholerae-suis**, all of which cause bacteraemia in the majority of cases. Typhoid has a longer incubation period of three to 28 days and illness is characterised by high and prolonged fever lasting several days, malaise, abdominal tenderness, weakness and sometimes the appearance of 'rose spots' on the trunk; constipation rather than diarrhoea may be a feature (Bryan et al, 1979).

Long term sequelae

Although episodes of diarrhoea caused by bacteria, viruses and protozoa are usually thought to be acute events, recent studies suggest that some patients may develop long-term sequelae (Archer, 1984, 1985). These include: malabsorption of essential nutrients which can result in compromise of the immune system and may lead to infection, allergy, autoimmune disorders and neoplasia. **S. typhimurium**, has been shown to cause malabsorption of vitamin B12 (Giannella et al, 1971) and to reduce food and water intake (Moore et al, 1977), and salmonella infection has been associated with reactive arthritis (Manicourt and Orloff, 1981; Puddy, 1982; Jayson and Grennon, 1983; Maki-Ikola and Granfors, 1992). Although reactive arthritis is usually of short duration, some patients may develop chronic disease and patients with certain underlying conditions (eg. haemoglobin abnormalities) may be prone to develop complications (Diggs, 1967; Adeyokunnu and Hendrickse, 1980; Marsal et al, 1981; Molyneux and French, 1982).

Faecal excretion

Faecal excretion of the organism will normally continue for a few weeks after recovery although use of ciprofloxacin has been shown to limit excretion in some cases (Diridle et al, 1986; Lahdevirta, 1989). In some individuals, who generally experience no symptoms, excretion may continue for months or even years (Anon, 1978b).

Treatment

Treatment of acute salmonella gastroenteritis with antimicrobial agents has been discouraged; the illness is usually relatively short and self-limiting and most cases cease excreting the organism within about five weeks, although some continue to excrete salmonellae for months. In less than 1% of cases, individuals become chronic carriers and continue to excrete for more than a year (Buchwald and Blaser, 1984). In addition, evidence suggested antimicrobial agents had little or no effect on the course of infection and may even have prolonged excretion or carriage of the organism (Aserkoff and Bennett, 1969; Smith and Badley, 1971; Nelson et al, 1980; Nye, 1981; Jewes, 1987). On the other hand, antimicrobial therapy is indicated for patients with systemic infection or very severe illness, although these account for only a small proportion of reported cases (see Chapter 3).

New antimicrobial agents such as ciprofloxacin have been shown to have some effect in treating severe illness (Patton et al, 1985; Barnass et al, 1989), and in reducing the duration of diarrhoea in patients with salmonella gastroenteritis, in rendering stools negative from salmonellas after 48 hours' treatment, and in the elimination of chronic carriage (Pichler et al, 1986; Lahdevirta, 1989; Sammalkorpi et al, 1987; Diridl et al, 1986). Ciprofloxacin appears to be very active against enteric bacteria, with relatively few and mostly mild side effects in adults, but its use is contraindicated in children and young adults up to 18 years (Rahm and Schacht, 1989). The potential economic benefits of using these antimicrobials to limit length of salmonella excretion in some specific circumstances is discussed in Chapter 5.

Infective dose

The infective dose for salmonellae appears to vary according to a number of host- and organism-related factors. These include strain differences in virulence, constituency of food vehicle, age and immune status of host (Bryan et al, 1979). Volunteer studies had suggested large inocula are required, but Blazer and Newman (1982) calculated doses of about 10 organisms in 10 of 12 outbreaks reviewed, and in an outbreak in the UK in 1982 due to contaminated chocolate, illness in some cases followed eating of a single chocolate bar containing less than 100 organisms (Gill et al, 1983; Greenwood and Hooper, 1983).

Reporting mechanisms for human salmonellosis and foodborne diseases

Human salmonellosis occurs world-wide although accurate data on global numbers of cases are not available. Developing countries where the problem is likely to be at its worst, often do not collect statistics, whilst those countries, mainly developed countries, which do, acknowledge their data reflect only a proportion of actual cases. Thus reported data is often a reflection of the availability of laboratory facilities and expertise in, and development of, surveillance systems.

There is variation between countries that collect data on foodborne disease, relating to the availability of information, agencies involved in data collection, type of information collected and definitions of terms (Gerigk, 1990). Reporting of salmonellosis will be subject to the same deficiencies as reporting of other foodborne diseases. Differences, however, occur between countries as to what is notified or reported, depending on the definition of what constitutes a case or outbreak of foodborne disease, making comparisons difficult*.

Whilst some countries have collected national statistics on foodborne disease for many years, for others this is a recent developement. Data on outbreaks of milkborne gastrointestinal illness were first published by the United States Public Health Service in 1923, with the addition of outbreaks due to all foods in 1938, although their present system for surveillance of food- and waterborne disease began in 1966 (Bean and Griffin, 1990). Detailed statistics on foodborne disease in Canada were first published in 1976 for the year 1973 (Todd, 1978). Food poisoning only became notifiable in England and Wales in 1938, and detailed statistics on food poisoning have been published since 1949.

Various agencies, including public health agencies, veterinary services and environmental health agencies, and government departments, may be involved in the collection and collation of data. Information capture is usually by statutory notification by physicians, central reporting

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*In some countries illness may only be recorded as foodborne if the same agent causing human illness was also identified in the food consumed; this may obviously result in under-ascertainment. In other countries an epidemiological association between illness and a particular food or meal is accepted, and in some countries all diarrhoeal illness is classified as foodborne, possibly giving misleading statistics. Definition of an outbreak may vary; the WHO definition describes an outbreak as comprising two or more people having a similar illness after eating the same food, whilst in some countries this has to be five or more cases (Gerigk, 1990).

of outbreaks, reporting of laboratory confirmed cases, family doctor (sentinel) surveillance schemes and special surveys. The sources of information relating to salmonella infection in England and Wales are described below and the observed trends in reporting are discussed.

Sources of information about salmonella infection in England and Wales

In England and Wales data for routine surveillance of food poisoning and salmonellosis are derived from three sources in particular:

a) statutory notifications of food poisoning to the proper officer for the district, usually the MOEH, by GPs or hospital clinicians, and collected centrally by the OPCS;

b) laboratory reports of cases and outbreaks of salmonella infection to CDSC by Public Health and hospital microbiologists;

c) reports of outbreaks to CDSC by local authorities.

Other, supplementary, sources of data including death registrations and clinical reporting are available (Noah and Sharp, 1979). The relevance to routine surveillance is limited, but may be of use in examination of long term trends. A diagram indicating how recorded cases and outbreaks are ascertained in England and Wales is presented in Appendix 1b.

Usefulness of laboratory and notification data in monitoring trends

The three main sources of information relating to salmonella infection: laboratory reports of isolations and outbreaks, local authority reports of outbreaks and statutory notifications of food poisoning, provide the most useful data for surveillance purposes. Each system is subject to bias. Statutory notification of food poisoning is included because, although not specifically for recording salmonellosis, trends appear to reflect very closely trends in laboratory reporting of human salmonella infection (see Chapter 3) (Galbraith, 1985).

Laboratory reporting of salmonella isolations and statutory notifications of food poisoning are used to monitor trends in infection in the community. The observed changes in the trends in reporting may be the result of real increases in the incidence of salmonellosis, or may result from inherent bias in the way data is collected, processed and analysed. These biases may affect the recording of data in two ways. First, they may be quantitative, reflecting changes in surveillance systems, variations in reporting practices and specimen referral for testing, improvements in laboratory methods, changes in the numbers of reporting laboratories or may be influenced by special studies, thus affecting the number of cases identified or reported by laboratories. Particularly important is the absence of routinely collected, patient-based, denominator data. Thus it is not possible to say with certainty from laboratory reported infections what the incidence of infection is or whether there has been a change in incidence of salmonellosis. However, an increase in the incidence of human infection can be inferred by detailed examination of the types of salmonellas reported, and supported by the observation of similar trends in independently collected but related data. Secondly, there may be qualitative effects resulting from changes in investigation practices, or changes in the amount and quality of information requested for national surveillance. The usefulness of these data as indicators of trends in salmonella infection can be assessed by the extent to which they fulfil criteria, as detailed below. In particular, comparison is made between laboratory reports and notifications.

Time-lag

First is the time-lag between infection occurring or the onset of symptoms and recording the affected individual as a statistic. Since one of the principal objectives of surveillance is to identify and investigate potential outbreaks of illness as early as possible, thereby limiting the impact in terms of the number and distribution of cases, the shorter the time-lag the better. The notification system was designed to keep this time-lag to a minimum by making notification a statutory obligation on the part of the attending physician, by requiring notification to be made on suspicion, so avoiding delay due to laboratory testing, and by ensuring that notification is made locally to the "Proper Officer" for the local authority district, who would have powers to investigate and control the situation. Delays in statutory notification may occur when physicians await the results of laboratory tests before notifying. The close similarity between trends in notifications and salmonella reports to CDSC may indeed indicate that doctors wait for laboratory results before notifying.

The time-lag for laboratory reporting may be greater. A comparison between date of receipt of specimen in the laboratory and receipt of a report by CDSC was made for a sample of 3,282 isolations recorded in England and Wales in 1989. For 99% the lag was between one and 13 weeks, with an average of four to five weeks (see Appendix 1c.). Two main factors affected this lag. First, the time of year: during the early part of the year the mean time-lag fell to about three and a half weeks, reaching as low as two and a half weeks in March. From June the time-lag increased and was almost seven weeks by the end of the year. This is explored further in Chapter 3. These increasing delays may reflect increased work-loads by routine and reference laboratories, particularly during the summer and autumn. These increases also occurred at a time when the number of staff in the laboratories may have decreased because of holidays, thereby exacerbating any delay.

Secondly, the length of delay appeared to relate to the type of salmonella. Thus, the mean delay was four to five weeks for the three most common serotypes but was over five weeks for all others. This was even more marked if the weekly time-lags were plotted. This showed sharp peaks of four to five weeks for the common serotypes, but a high proportion of other serotypes with time-lags in excess of this (Appendix 1c.ii). The main explanation for this was likely to relate to the way specimens were handled by the reference laboratory. The common serotypes are usually phage typed upon receipt at the reference laboratory, which is a relatively quick procedure, whereas many of the others required a more detailed identification procedure.

These trends were based on analysis of 1989 data only, the first year for which this information was available, and their significance would need to be tested over a longer period. However, the data does indicate the potential effect of laboratory delays in reporting trends.

Representation

The second criterion by which the main sources of data are judged is the extent to which reported cases are representative of all cases which occur. This relates to both the geographical distribution of cases and the range in type and severity of illness. Local policy on reporting and notification, individual biases of reporters, varying levels of expertise in laboratory identification and commitment to reporting may all affect the distribution of reports. Therefore data relating both to geographical distribution of cases and data on the "person" need to be interpreted with caution (see Chapter 3).

There is currently no reliable way to estimate how accurately notified and laboratory reported cases represent all cases, although it seems plausible that cases who see a doctor probably represent the more severely ill. However, the Richmond Report (Report of the Committee on the Microbiological Safety of Food, 1990), recommended a study of infectious intestinal disease in the population be carried out to examine this. Notified cases should be less subject to selection biases compared with laboratory reported cases since there may be greater selectivity for laboratory testing, relating to severity of illness, age and recent travel history, which may affect whether or not specimens are taken for examination. In 1982 another category, of "otherwise ascertained" cases, was introduced; this enabled MOsEH and EHOs to record cases identified in outbreak investigations.

Regularity of reporting

Analysis of trends by time, place and person is dependent on the regularity of central reporting. This may be affected by arbitrary local decisions about frequency of reporting and what will be reported, by changes in diagnostic techniques, by public or scientific interest in a "new" agent and by external factors such as postal strikes. Since many of these factors act locally rather than nationally, it is assumed that they either cancel each other out or their effect on national figures is temporary, and that national data give a reasonable indication of trends in the population. An examination of regional patterns in notification of food poisoning and laboratory reported salmonellosis is presented in Chapter 3 specifically to compare regional and sub-regional trends. Future introduction of, for example, electronic transfer of data at all levels would overcome many of these difficulties and result in virtual real time recording of infections.

Consistency and accuracy

A factor which may affect time trends particularly is consistency in reporting. There are generally agreed criteria for the diagnosis of food poisoning with regard to notifications, and ensuring accuracy in laboratories in the identification of salmonellas.

Notification statistics may be more affected than laboratory reports in this respect, in that notification is made on suspicion that infection is caused by something eaten and may include other gastrointestinal infections. The decision to notify may be dependent on a number of factors such as time and cost, and may also be extended to other foodborne illness. For example, there has been increasing evidence that campylobacter, a major gastrointestinal pathogen, is likely to be foodborne; acceptance of this may lead to increasing inclusion of confirmed campylobacter infections in notification statistics. Although laboratory reporting may be subject to similar factors, the accuracy of identification may be less variable in that many laboratories contributing reports to CDSC participate in a quality control scheme operated by the PHLS, which monitors diagnostic standards. In addition, many laboratories send cultures of salmonellas for reference laboratory confirmation of serotype or for phage typing.

Under-reporting

It is recognised that, however comprehensive the system for collecting data, reported illness represents only a proportion of actual cases. Estimates of under-ascertainment vary depending on the assumptions made and methods of calculation. Thus, estimated annual totals for cases in the USA ranged from six million to 81 million, and rates of under-reporting were estimated at 1:30 to 1:150; the WHO has suggested that only about 10% of incidents in most European countries are reported (Hauschild and Bryan, 1980; Archer and Kvenberg, 1985; Todd, 1987; Garthright et al, 1988). Differences in health care systems and methods of ascertainment between countries indicated caution when making comparisons. They do, however, indicate levels of under-ascertainment may be high and should be investigated.

The levels of under-ascertainment for England and Wales are unknown although extrapolation of a MAFF report in 1988 indicated that only one of 38 actual cases was reported centrally (Sockett and Roberts, 1989). Considerable under-notification of some notifiable diseases has been demonstrated (De Alarcon and Lewis, 1971; Haward, 1973; Goldacre and Millar, 1976; Clarkson and Fine, 1985; Jenkinson, 1983) and there is no reason to suspect that food poisoning is different. Reasons for not notifying include uncertainty of diagnosis, forgetting to notify or ignorance of which diseases are notifiable. Financial incentives have had little effect on increasing notification (McCormick, 1987).

Laboratory reporting of confirmed salmonella infection is affected by factors which include individual doctors' decisions on specimen taking and local policy on reporting to CDSC as well as the need of the patient to seek treatment. Nevertheless, the system provides valuable data on trends and has important features. The quick turnover of data, whereby reports sent by laboratories are analysed and published four weekly in the CDR, thus enabling microbiologists, public health and environmental health workers to be kept aware of trends and potential problems. Reporting of salmonella serotypes and phage types aids early detection of outbreaks, especially when the food vehicle is widely distributed (Gill et al, 1983; Cowden et al, 1989a), or may reveal changes in incidence of particular serotypes or phage types.

Quality of data

There has been little attempt to assess the quality of outbreak data in terms of the accuracy with which laboratory report forms are completed. Two projects attempted to evaluate the quality of data produced by the local authority reporting scheme introduced in 1981, both unpublished*. These studies identified deficiencies including inconsistencies between numbers of known cases and numbers notified, incomplete returns and misunderstanding of questions, as well as failure to report incidents known to have occurred. Two local authorities did not use the report form and a third was not aware of it existence. Despite these problems use of the form increased the number of outbreaks reported by over 10% between 1981 and 1988 (CDR 1988, No 8, unpublished).

The validity of data relating to food vehicles reported on outbreak forms was assessed in a report in 1986 (Anon, 1986). This indicated that in only a small number of outbreaks due to **S. typhimurium** in which

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*Dr RT Mayon-White analysed reports from the Oxford region and a group of undergraduate students at Reading University surveyed 50 local authorities in England and Wales, of which 39 replied (RT. Mayon-White, personal communication; unpublished data).

a food vehicle was reported, in the years 1982 to 1984, was there supporting evidence that the suspect food was the vehicle; ie. the same organism causing human illness was also identified in the food and/or there was an epidemiological association between eating a food and illness. The level of proven association also appeared to vary with the type of food and the organism, and this is explored in Chapter 3.

Summary

To identify strategies for effective prevention of salmonella infection a detailed understanding of the factors influencing reporting trends is required. This includes both a better understanding of the sources and quality of available data to aid interpretation, and exploration of the factors which may affect the incidence of the disease. Chapter three presents a detailed analysis of data relating to foodborne infections and salmonellosis in England and Wales and examines some of the factors which may have influenced the trends identified.

Chapter 2

THE ECONOMIC IMPLICATIONS OF HUMAN SALMONELLOSIS

Introduction

This chapter examines the rationale behind the economic evaluation of salmonellosis and describes the social and economic implications of human salmonella infection. The approach to costing and validity of the reported costs of infection are discussed and an assessment made of the value of economic appraisal of preventing foodborne salmonellosis.

Economic evaluation in public health

Public Health ..... "the science and art of preventing disease, prolonging life and promoting health through organised efforts of society."

Report of the Committee of Inquiry into the future development of the Public Health Function (1988)

The modern public health function was founded in concern with sanitary hygiene, the control of epidemic disease, the growth and concentration of population in towns and cities and the recognition of the poor health of the population from the 17th Century onwards. Particular influence on the early development of the public health movement and the bringing to public attention of the plight of the general population and promoting action to alleviate the worst effects of poverty is accredited to a number of figures including: Sydenham (1624-1689), Mead (1673-1754), Howard (1726-1790), Percival (1740-1804), Bentham (1748-1836), Lord Shaftesbury (1801-1885), Farr (1807-1883), Simon (1816-1904), and many others. Important, if not immediate, impetus in the early part of the period was given to the debate on the value of public health action by the discovery that specific measures could be used to cure or prevent specific diseases; eg. Lind's work on scurvy and Jenner's promotion of smallpox vaccination (Lind, 1755; Jenner, 1800a, 1800b; Royal Commission, 1898; Anon, 1923). These examples were important, both because they worked and were reproducible, and they could be used population-wide.

The public health function was broadened to encompass all those activities of society which act to minimise injurious environmental, social and behavioral influences, with establishment of the principle of government responsibility for the health of the population, as embodied in the Public Health Acts of 1848 and 1875 (Chave, 1984). Increasing emphasis was given to improving life-style and to the early diagnosis and treatment of disease. This was facilitated by legislation acting directly or by enabling local authorities to take action*.

Influence of economics on the development of public health

Early advocates of public health measures, including Petty, Chadwick and Farr in this country, and Shattuck and Calkins in the USA, used economic arguments for the introduction of public health measures. Their contribution was three-fold.

Economics verses altruism

First, they showed that policy could be argued on economic grounds. Chadwick (1842) maintained the "annual loss of life due to filth and bad ventilation was greater than in any war in which the country had ever been engaged". The sanitary and other measures he proposed were seen as "good economy" which would extend life expectancy and therefore productivity. His arguments were based on a belief that poverty and disease were directly related and that reducing disease would result in less poverty and therefore decrease demand upon the Poor Law.

Expenditure on public health was presented as an investment in human capital which benefited the national economy. Calkins, commenting on sanitary legislation in England from 1875 to 1890, noted that the death rate in England declined between 1880 and 1889 and that the value of lives saved, based on Farr's estimated value of life, was $650 million compared with $583.5 million spent on sanitary improvements. Calkins concluded: "Thus in ten years the country has more than regained the sum that was spent for sanitary improvements in the fifteen years; and

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*Safety and health education, screening and vaccination programmes, prevention of zoonoses in animals are all utilised in public health measures. These imply that the public health function is largely a preventive one which seeks either to reduce the incidence of disease or injury (primary prevention), or by intervention to reduce the prevalence of disease by identifying and removing the cause (secondary prevention) (Last, 1988).

in this calculation nothing figures for maladies avoided ... spared grief, better health and happier life" (Calkins, 1891).

Dublin and Whitney advocated that those involved in public health work should learn to use economic arguments when presenting their case for action and funding (Dublin and Whitney, 1920). They calculated an estimated loss of life expectancy of two and a half years for cases of tuberculosis, representing an annual productivity loss to the nation of $26.5 million. They suggested that costs associated with health care, economic effects on the family of a sick individual and losses from disability at work would be significant and should be taken into account, although they did not estimate these costs. Fein (1971) pointed out that in early economics literature similar arguments can be found regarding "the economic value of education, of acquired skills, of better health, and to the economic costs and gains of war, emigration and immigration."

The value of life

The second contribution was to introduce the idea that the life of a person could be valued in monetary terms thus enabling the effects of activities affecting life expectancy to be quantified. Early writers used a "human capital" approach; for example Petty, writing at the end of the 17th Century, estimated values of life at between £60 and £90, based on the productivity of each individual over his/her working life (Petty, 1690). The importance of this work lay, not so much in his methodology, but in applying these values to the advocacy of specific policy issues. Chadwick based the value of a person on the cost of bringing up a child and the number of productive years of life, and used these estimates to calculate the cost of disease and early death resulting from poor living and sanitary conditions (Chadwick, 1842).

Farr also valued the individual on his or her future earning potential, but recognised that a certain level of capital was invested in the rearing of a child and in maintenance, particularly in later life. Thus the value of an individual was greatest during the most productive years and became negative in extreme old age when costs of maintenance exceeded income. Using his life tables, Farr estimated values for a Norfolk agricultural labourer which were used to justify concern about the high mortality associated with various diseases, violence and childbirth (Farr, 1855). Fein pointed out that Farr's method was very similar to those used today and that this "human capital" approach was applied to a number of specific areas including costs of war, general taxation, emigration and immigration between 1880 and 1920.

Although at least five approaches to valuing life have been described Cooper and Rice (1976) suggested only two of these; the human capital (HC) and willingness-to-pay (WP) approaches are applicable to cost-of-illness studies. The other three, implicit values of life (VL) based on past decisions, explicit statements made in the public sector and implied values of individuals based on insurance assessments, are subject to poor information about the basis for the statements made or suffer from inconsistency. There are, however, drawbacks to both the HC and WP approaches. First on moral grounds, that the HC approach in attempting to value life on the future production potential of an individual can give higher or lower values depending on age, sex and race (Rice and Cooper, 1967). This method, adopted by William Farr, has nonetheless been commonly used by economists. Marin (personal communication) however, advocates the WP approach which measures the value of life in terms of what individuals would be willing to pay to reduce the risk of death or disability. This approach has drawbacks relating to the validity and consistency of the values derived, but is "more consistent with standard cost benefit procedures" (Marin; 1986).

The idea of valuing a life has not been without its critics. In 1913 Chapin expressed cynicism about the effect of economic argument in the public health sector, particularly when based on estimating a monetary value of life. He stated "it needs no argument to prove that it is good to be well and that it is wise to spend money for health. It is proper to consider cost in relation to results and financial savings, when such can be figured with accuracy, but there is much in the world which cannot be measured in terms of money ..." (Chapin, 1913). Broome (1978) has argued that it is more or less impossible to value life in monetary terms. His argument was based on a definition of cost-benefit analysis as a compensation test and the assertion that there is no finite value of life. The result of this argument is that any project which will potentially result in even one death would be rejected (see footnote* next page).

Roberts (1974) pointing out that in many early studies a "simple aggregate model of the economy was used to derive a value of man, and this figure is then applied to the epidemiological data". This approach sees each individual as a unit of investment within the overall national economy and takes no account of the effects of illness or disability on the family or society which result from that individual's decreased efficiency and increased needs.

Current debate centres around the methodology of valuing life rather than whether or not it is possible. Renewed interest in economics in the health sector since the 1950s (Fein, 1971), and more particularly in the UK since the 1970s, and the need to assess the effectiveness of care programmes or policies has also led to attempts to evaluate quality of life (Torrance et al, 1972; Sackett and Torrance, 1978; Churchill et al, 1984).

Development of techniques of economic evaluation

Thirdly, the techniques of economic evaluation, principally in the form of "cost-benefit" analysis, albeit in primitive form, was developed. Petty (1667), for example, in his plan "of lessening ye Plagues of London" estimated that every pound invested in preserving lives from the plague would yield a return of £84. Calkins (1891) in his assessment of the impact of sanitary legislation in England, utilised the idea of comparing the economic value of lives saved with the necessary expenditure required to preserve those lives.

Economic methods such as cost-benefit and cost-effectiveness evaluation were developed to assist policy-making in the public sector where normal market forces are prevented from operating. In the UK health sector, for example, demand for services is not modified by the patient having to meet the cost of treatment at the time of use; supply is influenced by perceived need and even public demand rather than by price, and choice of type and place of treatment may be limited so

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*Williams (1979) and Jones-Lee (1979) have suggested Broome's argument was flawed and represented a special case, and that the usual approach is to offer the individual the opportunity to choose between improvement in the standard of life and an improvement in expectation of life. Thus, for example, the argument against using the whooping cough vaccine on the slight chance of death or brain damage from the vaccine ignores not only the considerable discomfort caused by the disease but also the greater chance of chronic sequelae or death resulting from infection.

there is little "competition", at present, for patients' custom*. The patient or "customer" is not usually in possession of enough information to make choices about what type and how much of a particular treatment or service is required, and therefore treatment decisions and policy making and implementation are usually based on the needs perceived by a third party, the health professional.

The resurgence of interest in economic evaluation in the health sector in recent years is evidenced by the increase in the literature, particularly relating to cost-benefit and cost-effectiveness studies, and has grown from a need to make choices about, and rank alternatives in use of, resources (Fein, 1971; Roberts, 1974; Dunlop, 1975). Two particular reasons for this are discussed in Appendix 2a.

Approaches adopted in estimating the economic burden of salmonellosis

Salmonella infection with other foodborne diseases has come under public scrutiny recently, largely because of the increasing numbers of cases reported and the association of many of these cases with widely eaten foods (Agriculture Committee First Report, 1989). As a result foodborne illness has emerged as an important public concern and measures designed to protect the population have been introduced or improved. Salmonellosis is therefore a legitimate target for public health action, including evaluation of its importance as a cause of morbidity and mortality and the economic consequences of these effects, and the development and economic appraisal of preventive strategies.

The approach usually adopted has been the "cost of illness" approach. Its advantages are three-fold: first, that it seeks to clearly define the categories of all costs involved; secondly, it allows comparison of the relative importance of each category; and thirdly, the tangible costs identified can have a monetary value ascribed to them relatively easily. Disadvantages include problems with quantifying intangible costs and valuing the activities of the young, the elderly, the unemployed, housepersons and the disabled. Nonetheless they should be included and various strategies have been explored to quantify them.

*With introduction of a market in the health sector this may change although resource constraints will continue to limit choice as far as the patient is concerned.

Where these costs have been included they have been a significant factor in calculations, although it has been suggested that overall "the cost of illness" approach gives a low estimate of the true costs (Harrington and Portney 1987).

Roberts (1991) suggests the willingness-to-pay approach might provide an alternative method of appraisal of the value an individual puts on avoiding food poisoning. This approach is more compatible with demand theory, however there is not necessarily a correspondence between the cost of an illness and the value a person would place on not having the illness. This approach is not well developed in the area of foodborne disease, although some surveys have attempted to identify consumer willingness to pay additional sums to purchase safer food. For example, a recent survey in the UK found that on average consumers would pay 13% more for food if the extra cost went into making food safer; however, 40% of those surveyed refused to pay extra and there was some indication that response was dependent on social class (Report, 1990). This variability, difficulties in reproducibility and lack of account of actual costs indicate this approach needs further explanation if it is to be of value in this sphere.

Difficulties also arise in constructing cost profiles which are related to the severity of illness. Some studies have accounted for this by ascribing cases to various categories depending on the level of treatment required. However, even within these categories there may be a range of severity. The treatment received may be partly a function of actual severity and partly a function of the individual's perception of need; this may be particularly so in individuals who do not require hospitalisation. This aspect is also important in apportioning costs to unreported cases, which may be less but not insignificant, and therefore needs to be explored in detail.

Thus, the cost of illness approach is an essential pre-requisite, in this context, to any WP study. Providing essential information about the size and distribution of costs against which WP estimates can be compared. In this thesis a cost of illness approach was adopted and WP estimates incorporated where cost of illness estimates would be unreliable or impossible to obtain (see Chapters 4 and 5).

The social and economic implications of human salmonella infection

The economic losses associated with salmonella infection have attracted increasing attention in recent years in the USA, Canada and Europe, although the impact may well be greater in developing countries for which little data are available. The costs are associated with the investigation, treatment and prevention of illness, and may affect the whole chain of food production. Thus the costs of salmonellosis fall into the public and private sectors and may be surprising both in terms of the levels of costs incurred and the variety of areas affected*.

Public sector resources may be diverted from preventative activities into the treatment of patients and investigation of the source of infection. In the private sector financial burdens may be imposed on industry in general and on the food industry in particular and, last but not least, on the affected individual and his or her family.

Factors affecting interest in economic evaluation of salmonellosis

Three factors in particular have influenced economists and others to direct their attention to the financial and social impact of salmonella infection. First, the dramatic increase in the number of cases in recent years in England and Wales, as indicated in Chapter 1 (Galbraith et al, 1987b; Galbraith, 1990). Second, the recognition that the costs associated with salmonella infection in particular, and foodborne illness in general, are high. Although the methods used in these studies vary estimates indicated annual costs of salmonellosis and other intestinal infectious disease in the USA were billions of dollars, and were hundreds of millions of dollars in Canada (Archer and Kvenberg, 1985; Garthright et al, 1988; Todd, 1989a,b; Roberts, 1989, 1991). These costs were dependent on estimated numbers of unreported cases and, in some reports, appeared to assume the same range of severity of illness in both unreported and reported cases. Although they may over estimate costs, they indicated the potential economic impact of these infections.

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*Where estimated costs are quoted in this chapter, these are given in the currency reported in the original paper.

Costs of individual outbreaks can range from thousands to millions of pounds or dollars and results may depend on the detail of costs in the study. The range of costs in 11 salmonella outbreaks in food service establishments reviewed by Todd for the period 1962 to 1984 was $57,423 to $699,400, whilst the costs resulting from an outbreak at a conference in Holland in 1981 was at least US$317,000 (see Appendix 2b) (Todd, 1985a; Beckers et al, 1985). Where a specific food product was involved the associated costs were higher; five salmonella outbreaks due to manufactured foods in North America between 1973 and 1982 gave direct costs ranging from $36,400 to $62 million (Todd, 1985b). High costs were also associated with two outbreaks in the UK in 1982 and 1985, due to manufactured foods and gave total direct costs of £379,000 and £14.6 million (Roberts et al, 1989; Anon, 1985a; Sockett, 1991a,b).

A third, more general, factor has been the growth in interest in the sphere of economic evaluation in the health care and public health sectors, which has followed government policy in the UK to focus attention on the need to contain public expenditure.

Relative costs of salmonellosis compared with other foodborne pathogens

Most information about the economic implications of foodborne infection, including salmonellosis, comes from case studies of particular outbreaks. These studies usually take the form of either a cost-benefit analysis of the returns to intervention or the potential returns to preventive activity (Cohen et al, 1983; Shandera et al, 1985; Yule et al, 1986, 1988a; Roberts et al, 1989), or attempt to assess the economic impact of either sporadic cases or a specific outbreak (Sanders and D'Alessio, 1964; Levy and McIntire, 1974; Cohen et al, 1978; LeClerc, 1978; Anon, 1979; Neilson, 1984; Sockett and Stanwell-Smith, 1986; Sockett and Pearson, 1987; Yule et al, 1988b; Barnass et al, 1989). Todd has taken a third approach and has reviewed the costs of foodborne disease resulting from outbreaks associated with specific sectors of the food industry for example poultry (Todd, 1980).

Analysis of the costs in 35 outbreaks reviewed by Todd (1985a,b) indicated their range was wide. Costs due to **S. aureus** and **C. perfringens**, in which illness is usually of short duration, had least impact and salmonella outbreaks, which affected more people for longer periods, had correspondingly higher costs. Botulism, which has high mortality and long duration, had very high costs. This result was dependent on the much larger numbers of salmonella cases recorded compared with the other pathogens. These results, however, have to be treated with caution because of the ad hoc nature of the studies that were conducted and the numbers of outbreaks recorded, particularly those due to pathogens other than salmonella, was small, and there was variation in the categories of costs included in the different studies. Nevertheless Roberts (1989, 1991) ranked salmonellosis as the most costly foodborne disease in the USA in an evaluation of foodborne disease costs by pathogen.

Estimates of the tangible costs of foodborne infection in England and Wales for 1988 gave a similar result in that overall costs of salmonella infection were higher than for other foodborne pathogens. The costs were influenced by the costs of health care and lost productivity due to sickness absence, and were dependent on assumptions about under-reporting and the range in severity of illness (Sockett and Roberts, 1989). Thus the economic importance of salmonella infection lay, not only in the fairly severe nature of the illness in some cases, but more particularly in the large numbers of persons affected, although many will have had only a mild illness.

Categories of costs

The costs associated with salmonellosis fell under the main headings of public sector costs and costs to families and society and their presentation in this review is reflected in the structure of the cost study results in Chapter 4. These may be subdivided into tangible costs, which are easily measured in monetary terms and intangible costs, which are not. These in turn are often further divided into direct costs which fall on the affected person or implicated food producer, and indirect costs which fall on other family members, e.g. travel costs to visit the sick relative. Since some costs may be included in more than one category particular care is necessary in aggregating data so as to avoid double counting.

Intangible costs are not directly measurable in financial terms but they are important to the description of the impact of illness. There is discussion about the methodology of valuing such costs, however the need to take them into account is agreed by economists (Cullis and West, 1979; Drummond, 1980; Mishan, 1982; Mooney, 1986). The intangible costs of illness include pain and suffering and, in a small proportion of salmonella infections, death. Death represents both a loss to the affected person and to the families involved, with possible financial implications, and potentially a cost to the economy in terms of the loss of the future production potential of the individual.

Public sector costs

Public sector costs included the investigation of cases, the investigation and control of outbreaks, and medical treatment. These activities impose costs, in the UK, on local authority EHDs, public health physicians, laboratories and government departments such as the DoH and the MAFF, as well as medical services including general practices and hospitals. These costs, therefore, ultimately fall on the public purse. The tangible costs associated with seven salmonella outbreaks reported in the UK are compared in Appendix 2c. The largest public sector costs were associated with two outbreaks due to manufactured foods and reflected the size and type of investigations resulting from widely distributed products. However, they were a small proportion of the overall costs, reflecting the relatively much larger society costs which were mainly losses to the food manufacturer.

Public sector costs were explored in detail in a cost-benefit analysis of intervention in an outbreak of salmonellosis in 1982 (Roberts et al, 1989). Public sector costs were the larger component and were incurred at two levels which related to local action by EHDs, health authorities and laboratory studies, and national action involving the CDSC and government departments or agencies. Treatment costs involved both primary care by the GP and hospital treatment. The relatively greater costs of hospital treatment, 91% of the overall costs of treatment were associated with only 20% of cases; this is similar to other studies in the UK and abroad (Yule et al, 1986; Cohen et al, 1983; Todd, 1985a,b).

Costs to society

Costs to society act at three levels. Direct costs of illness which fall on the person who is ill and their family, and costs to the economy which relate to absence from work. Last, association of a food or retail outlet with food poisoning can have major repercussions for the producer, manufacturer or retailer (Report, 1990).

Costs to individual and family

Direct costs to individuals and their families may include seeking treatment, medicines, income loss and costs of care. Indirect costs include disability, and loss of income resulting from having to change vocation and accept a lower wage; this may include retraining. Changes in lifestyle, particularly eating habits, may result in some foods or restaurants being avoided and more expensive, and perceived "safer", alternatives being purchased (Harrington et al, 1985). Roberts (1991) argues that a "risk aversion" cost should be included in cost of illness estimates to reflect, for example, willingness to pay increased insurance premiums where there is a perceived increase in risk of disability or death associated with a particular activity (Landefeld and Seskin, 1982). Little detailed information on the profile of these costs exists in the context of foodborne illness in England and Wales. There are also difficult to value, intangible effects resulting from the discomfort of illness and disruption caused to normal activities, absence from schooling, loss of leisure time and death. Evaluation of these effects is difficult and not well developed. Nevertheless, they are considered by economists to be an important component of any study seeking to appraise the costs and benefits of alternative actions and where relevant alternative methods of evaluation are presented in this thesis (see Chapter 4) (Mishan, 1971; Drummond, 1980; Graham and Vaupel, 1981; Mooney, 1986).

Cohen (1982) made estimates based on MoT data for assessing injury and adjusted these for levels of severity of illness. The same approach was adopted by Roberts et al (1989); however there are difficulties with this approach. How well, for example, do the levels of severity of salmonellosis compare with an accident injury; i.e. is moderately severe diarrhoea equivalent to a broken arm? Little information about the severity profile of salmonellosis is available. Some information can be derived from the type of medical service sought by individuals, thus "death", "hospitalisation", "treatment by a GP" and "no medical attention sought" were categories used by J Roberts et al (1989) and T

Roberts (1991). Within these categorisations there is likely to be a range of severity which may be related to the patient's physical condition and to the individual's own perception of how ill he/she is*.

Can one value be used to cover the range of effects or should they be costed separately? If so on what basis should they be costed? Curtin (1984) used a similar approach to that of Krug and Rehm (1983) and evaluated loss of leisure at the same rate as loss of productive output, allowing different amounts of leisure time for weekdays and weekends, and included a gender and age differential and assumptions about employment status in the calculation of average hourly wage rates. This approach assumed that leisure time was valued at least as much as time spent at work; however, individuals may value leisure differently. Two approaches may be: either to base estimates on what individuals spend to purchase leisure activities as an indicator of how leisure is valued, or adopt a willingness-to-pay approach.

In a proportion of salmonella associated deaths recorded annually salmonella infection contributed to, or was the cause of, death. Account, therefore, needs to be taken of both the loss of life and the contribution salmonella infection actually made to the death of individuals. Differentiation should be made between those where salmonella infection caused death, those where infection contributed to death and those where infection was incidental. It therefore becomes necessary to explore these possibilities if a reasonable estimation of the value of lives lost is to be made. Basing the value of lives lost simply on application of a monetary figure to deaths where salmonella infection was recorded would over-estimate costs.

The approaches to valuing loss of life were based on implied values (VL), human capital values (HC) or willingness-to-pay (WP) estimates, or a combination of these (Rice and Cooper, 1967; Mishan, 1971, 1982; Cohen et al, 1983; Marin, 1983). Landefeld and Seskin (1982) proposed a method combining the HC and WP approaches** which gave a mid-range

*An alternative approach utilizing a severity index, developed for this study, based on the cases' assessment of severity of illness is presented in Chapter 4.

**Landefeld and Seskins' (LS) approach incorporated non-labour income, risk aversion and risk reduction activity.

estimate of the value of life between the HC and WP approaches (Roberts, 1988). The values identified were high and could result in a considerable increase in the estimated costs of illness. Thus the calculation of illness costs and the evaluation of preventive measures using the cost-benefit approach may be very sensitive to the values ascribed to lives lost. In cost-benefit studies of milk pasteurisation and poultry irradiation in Scotland the results were sensitive to assumptions about numbers of lives lost and to the method of valuing life. In a study of **S. napoli** infection in 1982 estimated values for loss of life were £190,000 and £15 million depending on the method used (Cohen et al, 1983; Yule et al, 1986; Roberts et al, 1989).

Lost production

Probably the most important society-related cost in terms of its potential effect on the economy is lost production. These costs may be generated by absence of the affected person and by family or friends taking time off as carers. Cohen (1983), Yule et al (1986) and Neilson (1984), estimated lost productive output was about half of all the tangible costs of the outbreaks they described. Production loss was calculated on the basis that the production potential of the individual was equivalent to at least the gross daily employment costs of that individual (Morgan and Davies, 1981). This is likely to be an under-estimate since, for example, it does not account for the profit to the firm which results from the employees' activities. Further debate may be necessary to allow for differences in wage rates which relate to age, gender and status within the company. For example, labour market data may under-value a woman's contribution to the labour force and adjustments removing the gender bias significantly increased productivity losses reported by Roberts et al (1989) (see Chapter 4). These effects may also be distributional where, for example, a labour force has particular age, gender or social class bias.

There is some debate about the extent to which absence from work affects productivity and in some instances the work will be made up either by slack in the system or by imposing extra work on other members of staff. Conversely, absence of a key individual may cause losses disproportionate to that persons apparent contribution. It could be argued that there is no productivity loss if there is unemployment in the system on the assumption that replacement staff can be taken from the pool of unemployed. Alternatively, unemployment is a matter for the macro management of the economy and evaluation of health provision should not be unduly affected by the ebbs and flows of cyclical unemployment. For salmonellosis presence or absence of unemployment is largely irrelevant as absence, in most cases, will be short and the costs of seeking alternative employees prohibitive.

Losses contained within the food industry

Losses may be incurred by the food industry as a result of illness or from withdrawal of contaminated products. These may represent a special case since many costs will be distributional and contained within the industry. The effect on the economy may therefore be minimal unless long-term unemployment results from, for example, loss of public confidence in a product, or plant closure. The government may step in to support a sector of the food industry if public confidence in a product is seriously undermined, and in this situation the taxpayer will ultimately pay the bill. For example, in 1988 the UK government made £7 million available to support the egg industry, following the reported association of **S. enteritidis PT 4** infection with contaminated poultry and eggs (Agriculture Committee First Report, 1989). Todd (1985b) reported that, after an outbreak in North America in 1973/74 due to contaminated chocolate, the producer went out of business. The Canadian government paid Can$3.6 million in grants to re-start the company, thereby offsetting costs of unemployment benefit.

Costs borne by the food industry at the producer, manufacture and processing, or service and retail stages include direct and indirect costs. Immediate loss of business may occur when a food service outlet or manufacturer is identified as a source of infection. Costs can be estimated from the business lost during the period of closure and may be distributional. For example, after withdrawal of Farley's infant feeds in December 1985 following an outbreak of **S. ealing** infection (Rowe et al, 1987), sales of infant formulas were largely unaffected, suggesting that parents switched to other brands. Care should therefore be taken when including these types of cost in the calculation of benefit-cost ratios or in costing national effects of food poisoning, although they are obviously directly relevant to the financial impact on an individual manufacturer or restaurant.

Where a product is implicated it may be recalled and held for the period of investigation and eventually destroyed. Recall may be expensive and involve national and local government agencies as well as the food industry, and product destruction must be counted as an outright loss. Withdrawal of a product or closure of a restaurant may result in decline in public confidence, which may then take years to recover, and may affect sales of similar products of different brands. A recent report indicated £257 million losses to the food industry following eight food scares between 1989 and 1990 (Report, 1990). Todd (1985b) identified recall costs in five outbreaks in North America, of $124.4 thousand to $58.3 million, 24%-99% of the total outbreaks costs. Recall costs of an outbreak in the UK in 1982 were £92,000, almost a fifth of the total costs (Roberts et al, 1989). Future loss of business following decline in public confidence had a major impact on the manufacturer in the **S. ealing** outbreak mentioned above. By 1986 (4 years after the outbreak), the company had only recovered half of its former market share; one production unit was closed and about 200 jobs lost (The Guardian, 7 April, 1989). Decreased product demand or restarting of a company will generate promotional costs. Following a botulism outbreak in Belgium in 1982 due to canned North American salmon, the Alaskan State government and the Canadian government spent $5 million (1983 prices) in product promotion (Todd 1985b).

Other direct costs may result from fines and the need for renovation and cleaning of premises, replacement of defective equipment and training of present or new staff. It could be argued that at least some of these costs, including items of capital expenditure on new equipment, may have occurred anyway and that the outbreak only brought forward the expenditure. However, since it is unlikely to be known when this expenditure was likely to have taken place, they could arguably be included in the direct cost of the outbreak.

Staffing costs may include salaries of staff suspended because they are excreting a pathogenic organism, or salaries of staff laid off whilst the premises are closed or being renovated and cleaned. Alternatively, costs could arise from temporary employment of additional staff to cover for those suspended or to help in cleaning.

Indirect costs can result from litigation or from increased insurance premiums; in most investigations these costs are difficult to obtain. Legal costs, can be huge and may account for a major proportion of total costs of an outbreak where they have been included. Litigation costs resulting from claims against food manufacturers and retailers have been significant in outbreaks reported in the USA and Canada (Mann et al, 1983; Todd, 1989a,b). Although not a commonly reported feature of outbreaks in the UK (Sockett and Roberts, 1989), the settlement of claims paid by a major UK airline following a salmonella outbreak in 1984, which resulted in over 600 cases in passengers and two associated deaths, was several million pounds (Burslem et al, 1990, British Airways Press Office, personal communication). In 1991 a farmer in England was ordered to pay £33,000 damages to the families of two customers who died from **Streptococcus zooepidemicus** infections after drinking contaminated raw milk (The Times, 2 February, 1991). The effect of legal action may not be adequately represented by the eventual awards; legal action may take several years to complete and cause considerable stress to all concerned.

Indirect costs may include a loss in the actual value of the company, for example through a decline in share values. For example, the company in the **S. ealing** outbreak had been on offer at £40 million but following the outbreak was eventually sold for £18 million, generating a £22 million loss in its value (Anon, 1985a; Sockett, 1991a).

National costs of salmonella infection

Few studies of the national costs of foodborne illness in general, or salmonellosis in particular, are reported in the literature. Costs of foodborne bacterial disease in the USA were estimated at $4.8 billion for 1987 (Roberts, 1988); salmonellosis accounted for $1.4 billion of this and was the largest single cause. Staphylococcal food poisoning and campylobacter infection accounted for about $1 billion each. This study estimated costs associated with medical care and productivity losses due to deaths, which was a major component. Other costs were excluded and the amounts stated, therefore, represented the minimum costs of disease. Estimated annual costs of salmonellosis were also reported by Archer and Kvenberg (1985) ($1.9-$2.3 billion) and Todd (1989a) ($4 billion) for the USA and Todd (1989b) ($846 million) for Canada. Although large, these costs these costs need to be interpreted in the context of the size of the economies of these countries.

The costs derived in these studies were dependent on estimates of the annual numbers of cases and on cost-per-case data obtained from a small number of studies of outbreaks. In most studies little allowance was made for the range of severity of illness, which may vary from very mild to death, and the average cost per case may not have adequately reflected the relatively mild illness which is probably experienced by most infected persons. Exceptions were the study by Roberts et al (1989) in which allowance was made for mild illness in most persons in estimating cost attributed to unreported cases, and the study by Roberts (1988) in which cases were ascribed to one of four severity classes related to deaths or the level of medical treatment required.

T Roberts (1989) pointed out that whilst some reported estimates have not included death, studies, principally by economists, have done so. Loss of leisure was a component of costs identified by Curtin (1984) but not included in other studies. The relative contribution made by the different categories may vary widely, however it is important to identify and quantify all costs (and benefits) if possible, where the cost-benefit approach is to be adopted (Drummond, 1980; Drummond et al, 1987). In particular focusing on estimating costs of using resources or loss of resources which would have had a positive opportunity cost associated with them and so be of economic significance.

Two studies of national costs of salmonella infection in 1977 were reported from the then Federal Republic of Germany and Canada (Krug and Rehm, 1983; Curtin, 1984). The studies relied, to some extent, on assumptions about levels of under-reporting of salmonellosis and there were differences in the categories of costs included, particularly for intangible costs. Important tangible costs relating to investigation of the cause of illness (German study) and the financial implications of illness to families were excluded. Both studies indicated that loss of production (including housewives' time in the Canadian study) and intangible losses due to leisure time foregone were major items. Tables summarising the costs identified are presented in Appendix 2d (2di,ii).

The aim of the German study was to identify measures to reduce the incidence of salmonellosis in humans, pigs, poultry, food, animal feeds and water. A cost-benefit approach was taken to determine the optimal measure or combination of measures to achieve this. The estimated annual costs of salmonellosis were DM 239.6 million. Infections in animals which accounted for over half this cost (DM 131.4 million) were mainly associated with infection in cattle, and calculated losses were based on expert opinion about the numbers of infected animals. Human salmonellosis accounted for 45% (DM 108.2 million) of the total.

The Canadian study used a similar methodology. The main differences were inclusion of costs relating to loss of life in the calculation of the costs of human illness and concentration on estimating costs to the poultry industry only. The cost of human illness, based on assumptions about levels of under-reporting of cases, was estimated at Can$83.7 million, with a further Can$2.8 million losses to the poultry industry.

Some assumptions made in the Canadian study, if applied to England and Wales, would result in underestimation of costs in some areas. Medical costs for reported, non-hospitalised cases were based on the cost of a single examination and an average of two laboratory tests. A study of sporadic cases of **S. typhimurium** infection in the UK in 1986 showed an average of two family doctor consultations per case (Sockett and Stanwell-Smith, 1986) (see Chapter 4). It was assumed that unreported cases in Canada had not seen a doctor and therefore no medical costs were incurred. This may also result in underestimation of medical costs since it pre-supposes that doctors report all cases they see, whereas this may not be true in practice. Costs relating to transport, hospital visiting and legal costs were excluded because of lack of data or difficulties in calculating them. Intangible costs due to pain and suffering were excluded because of the uncertainty concerning the methods of evaluating such costs. Although similar considerations related to evaluation of loss of leisure and value of life, these were included. The authors suggested the costs detailed should be seen as minimum costs, thereby adding weight to the final values given.

No other detailed study of the costs of human salmonellosis in England and Wales has been reported in the literature. Estimations of costs of foodborne illness have been made or extrapolated from studies of costs associated with outbreaks or sectors of the food industry (Sockett and Stanwell-Smith, 1986; Sockett and Roberts, 1989; Report, 1990).

Costs and benefits of preventing salmonella infection

The value of economic appraisal of salmonellosis is three-fold. Firstly, in bringing to public attention an essentially preventable illness; and secondly, in identifying those areas, particularly in the public sector, which consume resources. However, the third and probably most valuable contribution, concerns the evaluation of procedures designed to limit or prevent the spread of infection.

The national studies for FRG and Canada sought to evaluate, through the cost-benefit approach, which particular measure or combination of measures could achieve significant reductions in human salmonellosis. Because of the lack of data relating to some cost categories and reliance on expert opinion in some areas, the value of these studies was to provide a model for looking at costs and benefits rather than provide firm estimates of these. Nevertheless, estimations of the costs and expected success of a number of control measures indicated that, for example, hygiene education aimed at both the domestic user and the food service sector would have benefit in reducing infection.

Elimination of contamination earlier in the food chain would seem more controllable and reliable, and therefore more desirable. Curtin (1984) indicated measures which could be taken during poultry production which may have a positive cost-benefit. A major problem with both studies was a lack of firm data on the effectiveness of specific control measures and therefore in estimating the potential benefits derived from them. The dynamics of the systems would also need to be examined. For example, the incidence of contamination of poultry carcasses exceeds that of the live birds, indicating cross-contamination during processing (Notermans et al, 1975; McBride et al, 1980).

The success of a measure aimed at preventing salmonellosis but which reduced all bacterial contamination (e.g. pasteurisation, irradiation) would have additional benefits in reducing other foodborne infections. The benefits would accrue over an extended period of time, therefore any calculation would need to contain, not only initial outlay and future maintenance costs, but also future reduction in cases. On this basis, a measure which was not necessarily cost-beneficial in the first year might become so in time (Yule et al, 1986).

Few detailed cost-benefit studies of specific control measures are reported. Although not a cost-benefit analysis, Levy and McIntyre (1974) suggested that estimated outbreak costs of $28,733 resulting from cross-contamination in a restaurant kitchen should be contrasted with the lower costs of primary preventive action such as hygiene education for restaurant food handlers ($500 per course attended by between 20 and 100 persons), and regular inspection of the premises by public health officials ($11 per visit at 1973 prices). In a cost-benefit study Cohen et al (1983) concluded that financial benefits would result from a ban on the sale of unpasteurised milk in Scotland if this eliminated milk-associated human salmonellosis. Sharp et al (1985, 1988) have shown that milkborne salmonella and campylobacter infection declined following introduction of such a ban in 1983.

In a similar study of the prevention of poultry-borne salmonellosis by chicken carcase irradiation, Yule et al (1986, 1988a) concluded the "public health benefits exceed irradiation costs". This conclusion was sensitive to assumptions about the numbers of reported cases and the costs per case. Estimations based on three levels of projected benefits showed this was negative for the lower projection but was positive for the mid and upper projections (Yule et al, 1986). Further benefit would be derived from the reduction of other poultry-borne infections such as campylobacteriosis. Finn and Mehr (1977), in contrast, found the costs of eradicating salmonella from poultry were prohibitively expensive and such an approach could not be justified on economic grounds.

Eradication may be prohibitively expensive, however reduction in human infection may be, economically, a more achievable goal. Krug and Rehm (1983) presented a model where optimum combinations of measures could be expected to achieve a reduction in human illness of up to 65%. This study attempted to identify measures or combinations of measures which would give a positive cost-benefit. Given external factors such as economic constraints on food production and customer tastes and requirements, this approach would allow a certain amount of freedom to choose, not only the most cost-effective measures, but also those measures which are most acceptable to the producer or consumer. Curtin (1984), like Krug and Rehm, also took the approach that a number of measures, although not all, could be used to reduce levels of poultry-borne salmonellosis. However, the results in both studies may have been affected by underestimation of the numbers and costs of cases.

The benefits of secondary prevention have hardly been considered at all and although the scope for action is limited to identifying the cause of a problem and eliminating it, the potential benefits may be large. These possibilities were explored by Cohen et al (1978) in a study of a salmonella outbreak attributed to contaminated cheese and in a study of a salmonella outbreak due to contaminated chocolate in 1982 (Roberts et al, 1989). The investigation costs of the latter outbreak at the point it was stopped (20% of product sold) were compared with projected costs of the outbreak had it continued until stocks of the imported product were exhausted. This showed that for every £1 expended on investigation there was a saving of £3.50 to the public sector and of £1.50 in lost production. Thus the potential benefits of these activities deserve further attention, although it could be argued that these benefits should also be offset against routine surveillance and other public health activities designed to identify such problems.

Summary

The relatively few published studies of the financial implications of salmonellosis suggest the costs are high but that prevention can be economically worthwhile. Most authors indicate the figures they present are underestimates, often based on incomplete data and dependent on assumptions or expert opinion. In order to provide a more accurate assessment of the costs of salmonellosis, as well as other foodborne disease, a number of methodological issues need to be addressed. These include the method of approach to costing foodborne illness, the relative contribution and valuation of intangible costs such as loss of life, estimation of levels of under-reporting and allowance for different degrees of severity of illness. There may also be considerable costs associated with the small number of cases who develop long-term sequelae to their original infection. These may last from months to the rest of the life of the individual. Little information currently exists on how many cases develop such sequelae and whether they can be ascribed to a particular incident. Taking account of the numbers of reported and estimated unreported cases and those who develop long-term sequelae, the economic impact of salmonellosis is likely to be of some significance.

Economic analysis has an important contribution to make in identifying where costs fall, and to the assessment of alternative preventive strategies. The WHO has recognised the importance of such studies and recommends that countries undertake assessment of the economic impact of salmonellosis and other foodborne disease (Anon, 1981b). Chapter 4 of this thesis seeks to identify and quantify the costs of illness, in England and Wales, to the public sector and society and attempts to explore factors, such as severity and social class, which may modify demand for services and therefore the costs of illness.

In Chapter 5 preventive issues and costs are drawn together and the potential for reducing costs through changes in case management and primary preventive activities is explored. The assessment of the costs and benefits of two alternative approaches to primary prevention in the poultry industry, are modelled. The aim is, therefore, to provide a model for a decision-making strategy which can be applied to preventive measures in food production.

Chapter 3

FACTORS INFLUENCING TRENDS IN REPORTED FOOD POISONING AND SALMONELLOSIS IN ENGLAND AND WALES: 1960 - 1989

This chapter is divided into three sections corresponding to methods, results and discussion. These relate to an examination of the factors which have possibly influenced trends in reported salmonellosis and food poisoning during the 30 years, 1960 to 1989. The methods section first describes the main sources of data from which information was extracted. Second the computer software packages used in data management and analysis are listed. Thirdly, the analyses are described, including the statistical approaches taken, under headings which correspond with the major subheadings in the results section.

The results section presents data on reported trends in laboratory reported salmonellosis for the period under review. Where relevant these were compared with the corresponding trends in notifications of food poisoning. The analysis explored seasonal, national and sub-national trends and sought to identify some of the factors which have influenced these trends. The influence of infection acquired abroad was assessed. Attention was given to an analysis of data relating to outbreaks of salmonellosis and other food poisoning so as to identify "at risk" foods. The incidence of salmonella infection in food animal species was examined and comparison was made of the trends in reporting of salmonella serotypes and phage types in man and animals. Factors which have influenced the availability and consumer preference for meat products was explored. The effect of ambient temperature on annual trends in salmonella reporting was examined.

The discussion examines the reasons why salmonellosis has become a matter of recent public health and political importance and seeks to answer questions about the validity of the trends identified, the severity of the problem and factors which may act to increase the risk of human salmonella infection. Consideration is given to factors which specifically affect foodborne transmission of salmonellosis. A method of assessing the risks associated with particular foods, thus aiding the targeting of preventive activities, is presented.

METHODS

Sources of data.

The sources of data relating to cases and outbreaks of food poisoning and human salmonellosis are described below. Other sources of data on salmonella infection in animals and statistics relating to population size and distribution, weather patterns, foreign travel and meat consumption are described in Appendix 3a together with listings of tables from which information was extracted, where appropriate.

The source, content, regularity, value and limitations of laboratory based data and notifications were discussed in Chapter 1. Comment here is limited to describing the information they provide.

Reports to CDSC.
These were of four types:

1. Aggregated totals, by serotype, of salmonella isolates from faecal specimens reported weekly by laboratories in England and Wales. No details of individual cases were provided before 1989. Laboratories were coded by NHS Region allowing analysis of these data by region. The phage type identified was not recorded by CDSC until 1983 for **S. typhimurium** and 1986 for **S. enteritidis** and **S. virchow**. From 1989 laboratories gave details of name, age, sex, dates of onset of symptoms and submission of specimen, and country visited if recently abroad.

2. Detailed individual reports, by laboratories in England and Wales, of non-faecal isolations from patients with bacteraemia, meningitis and other complications, and patients who died. Information included age, sex, organism isolated, site of infection and clinical presentation.

3. Detailed reports of outbreaks of food poisoning and salmonellosis to CDSC by laboratories in England and Wales. These included information about the agent causing illness, numbers of persons involved, suspect or confirmed food vehicle and place where the food was eaten.

4. Detailed reports of outbreaks of food poisoning and salmonellosis to CDSC, since 1980, by local authority EHDs, MOsEH or CsCDC.

Food poisoning notifications and death registrations (OPCS).
Data on food poisoning notifications provided the following information:

1. Aggregated totals of food poisoning for England and Wales. This was available as annual, quarterly, monthly and weekly totals.

2. Food poisoning totals by NHS Region and by LA district.

3. Food poisoning totals by age and sex of case.

Similar details were available for death registrations (salmonella infection or other bacterial food poisoning was the underlying cause of death).

Software packages.

The computer software packages used for data management and statistical analysis are listed below:

Data management.
The spreadsheet package Supercalc 5 produced by Computer Associates International, Slough, Berkshire was used for data management (Computer Associates International Incorporated, 1989).

Statistical analysis.
Statistical analysis was performed using GLIM (Payne, 1983).

Analysis of data.

The approaches taken to analysis of the data are described under main headings corresponding with those in the results section. Data from published studies not described under sources of data are referenced in the text. As a general principle actual data and rates were presented (rates are expressed as per 100,000 unless otherwise stated). The significance of results was tested, unless otherwise stated, using chi-square or t-tests at the 5% level (two tailed) as appropriate (Armitage and Berry, 1971). Where other statistical methods were applied to test specific hypotheses these are described below.

Trends in annual reporting of food poisoning and salmonellosis.
Analysis of trends was based on notifications of food poisoning and laboratory reports of salmonella isolations, and registered and laboratory reported deaths. Annual and sub-annual totals and rates of reporting were compared to explore annual, seasonal, regional and age and sex variations. From 1989 salmonella isolations reported to CDSC included date of specimen receipt by the laboratory. This was likely to be the closest reliable date available to the onset of illness and it was assumed this would give a more accurate indication of when illness occurred than the week of report to CDSC.

The variation of regional notifications of food poisoning and laboratory reports of salmonellosis from the national average was compared to explore the possibility of local patterns. To test the hypothesis that certain phage types of **S. typhimurium** had a significant effect on salmonella reporting in Yorkshire Region, which consistently had high levels of reporting compared with other Regions, a generalised linear model with a Poisson error structure and corrected for overdispersion was fitted to the data (McCullagh and Nelder, 1989). The dependent variable was **S. typhimurium** phage types 10, 12 and 49a, and assumed $r_{ij} \sim$ Poisson (λ_{ij}) for region i and year j where:

$$\text{Log } \lambda_{ij} = \log N_{ij} + \log \frac{\text{typed S tym } ij}{(\text{S tym } ij)} + a + \text{Region } i + \text{Year } j$$

Data on both registered and laboratory reported deaths were analysed as annual rates and by age and sex of cases. Similarly, laboratory reports of salmonella bacteraemia and other complications were analysed by annual total reports and as rates and by serotype isolated.

Serotypes reported.
Information on the reporting of specific serotypes was obtained from laboratory reports to CDSC. The data was analysed by frequency of reporting over time. The influence of specific serotypes on trends was examined. Particular consideration was given to the most commonly reported serotypes, **S. enteritidis** and **S. typhimurium**.

Infection acquired abroad.
Information about recent travel of persons with salmonella infection was only available for 1989 when laboratories began reporting this to

CDSC. Analysis of the 1989 data was by serotype and country of visit. To compare the risks of acquiring infection for the main countries visited the risk of infection for each country was calculated as:

$$\text{Risk of infection} = \frac{\text{Infected visitors returning from country X}}{\text{Number of visitors to country X/100,000}}$$

To explore the possibility that visits to different parts of the world made different relative contributions to the overall annual geographical distribution of reports, seasonal trends were explored using the date of receipt of specimen by the laboratory as the best available indicator of when the person became infected. The number of infections, by month, were plotted by area of destination where there were sufficient reported infections to indicate a trend. This assumed that most individuals would have sought medical advice about their infection soon after returning to the UK, and that the specimen was therefore taken soon after return from abroad.

Place of outbreak.

Laboratory and local authority reports were analysed to identify the place where outbreaks occurred. It was assumed that for most outbreaks this also reflected the place where the food was prepared and served (if foodborne) or where individuals became ill (if not foodborne). The analysis sought to compare trends in place of outbreak, associated causative organisms and cases associated with outbreaks.

Food vehicles associated with outbreaks.

To identify foods which were particularly associated with salmonella infection, outbreaks reported to CDSC, in which a suspect food was mentioned, were analysed for the period 1960 to 1989. The data were analysed by the organism identified and type of suspect food recorded. A food was described as "associated" if recorded on the outbreak report as the suspect vehicle of infection. However, for many reports, no microbiological or epidemiological evidence was given to confirm the association. Further comparisons were made by type of organism and food for outbreaks where there was microbiological and or epidemiological evidence of association between eating a food and illness.

Analysis was made of outbreaks associated with manufactured foods.

which are often distributed widely and may be produced in large quantities. These products have the potential to affect large numbers of people. For this analysis a manufactured food was defined as "any product of the agricultural industry that had been converted into a consumer product by any process of heat treatment, drying or curing, or fermentation" (T. Baird-Parker, Unilever, personal communication).

Infections in animals.
To explore the relationship between salmonella infections in humans and animals, analysis was made of trends in reported incidents in cattle, pigs, sheep and poultry from 1976 (Data for 1960-1975 is summarised in Appendix 3b). Attention was given to overall trends in reporting of salmonella infection and in reporting of specific serotypes and phage types, particularly those types which are commonly recorded as a cause of human infection: **S. enteritidis**, **S. typhimurium** and **S. virchow**.

Patterns of food consumption.
MLC estimates of annual meat supplies were used to indicate patterns of meat consumption in the UK. It was assumed that the patterns would be the same for England and Wales. These data were used to identify trends in consumption of specific types of meat (1966-1989). The possibility that other factors relating to storage and retailing also affected consumption was explored by analysis of consumer expenditure on meats and meat products, availability of domestic freezers and refrigerators, seasonality of purchases and patterns of meat retailing.

Influence of annual trends in ambient temperature.
To explore the possibility that ambient temperature influenced trends in salmonella infection, annual totals were regressed against annual average temperature and annual average summer temperature based on combinations of months (May, June, July; June, July, August; June, July, August, September) for the period 1962 to 1989. The significance of any association between temperature and salmonellosis was tested by comparing the estimated temperature effect with its standard error by a series of linear models (McCullagh and Nelder, 1989). Calculations were performed in GLIM. Where outlier observations were recorded, their leverage on the model was estimated; allowance was also made for the underlying increase in salmonella reports over the period.

RESULTS

Trends in reporting of salmonellosis and food poisoning: 1960-1989

Comparison of trends for laboratory reports of salmonellosis with notifications of food poisoning showed that both exhibited a continuous and steady increase up to 1985. Thereafter the rates increased but that of notifications being greater (Figure 3.1a,b). Salmonella reporting rates more than doubled (9-24) in the period 1960 to 1984, whilst notification rates also increased (17-26). However, reporting rates for salmonellas doubled again (24-49), and notifications tripled (26-75) in the next five years 1985 to 1989.

Seasonal variation.

Salmonella infections showed a marked seasonal pattern with major peaks reported each year (Figure 3.2). From 1975 to 1981 the peaks were sharply defined but after 1982, when annual totals were increasing, the main peak was truncated. Annual peaks varied between maximum monthly totals of about 1,000 and 2,500 reports from 1975 to 1986. From 1987 onwards the peak month total increased to between about 3,000 and over 4,500. In most years a smaller, secondary, peak was observed in January and probably reflected outbreaks over the preceding Christmas period. When plotted as monthly totals for 1989 the date of specimen receipt by the laboratory indicated that incidence of infection began to increase from April rather than May, as indicated by data based on date of report to CDSC, and that a well defined peak was observed in August and was followed by a sharp decline (see Appendix 3c).

Regional trends in reporting (1975-1989)

To assess the extent to which salmonella infection affected notification at a Regional level, annual rates were compared for notifications and laboratory reported salmonellosis (Figure 3.3). For most regions the trends in the patterns of reporting and in the actual rates were similar. This was particularly so for the period 1975-85 when, in several regions, salmonella reporting rates were higher than notification rates. During this period the rates showed a two- to three-fold increase overall from 10 to 30. Yorkshire Region was, however, consistently high during this period at between 25 to 45 (see footnote* page 79). From 1986 onwards all regions showed a further

Figure 3.1a

Trends in Laboratory Reports of Salmonellosis and Notificat ons of Food Poisoning
England and Wales: 5 year moving averages 1964 - 88

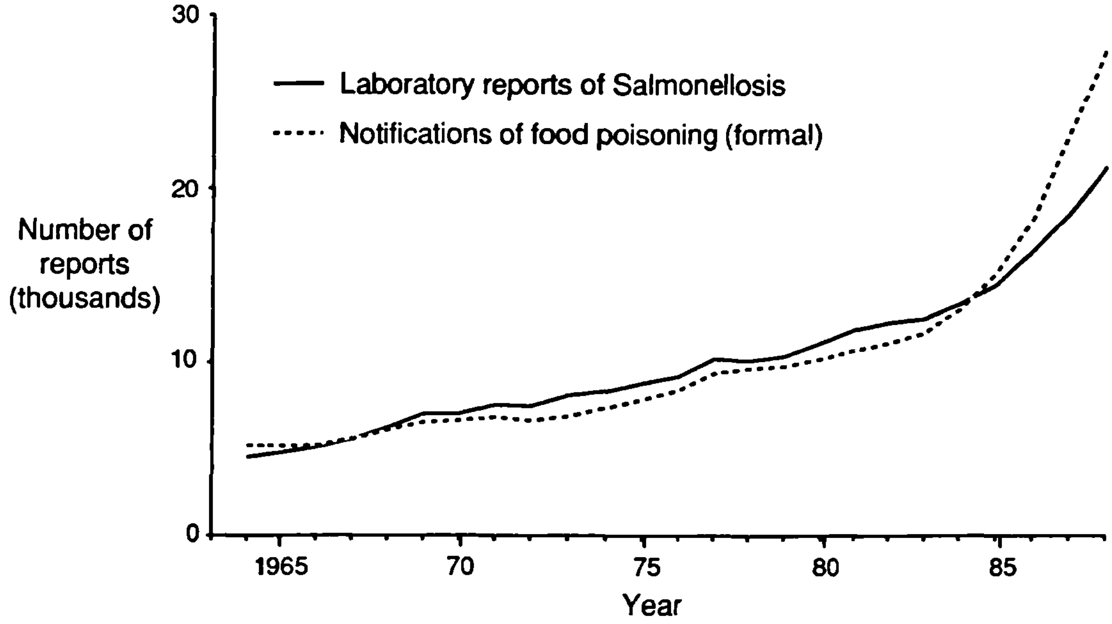


Figure 3.1b

Salmonella Reports from Laboratories and Food Poisoning Notifications
England and Wales: reporting rates 1960 - 89

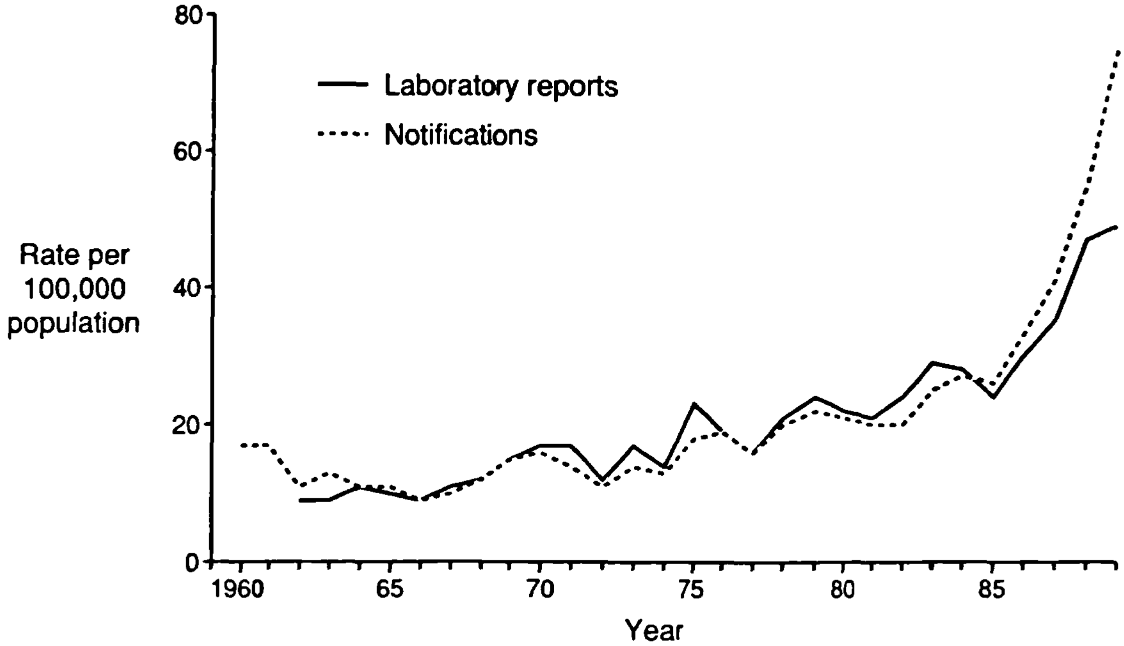
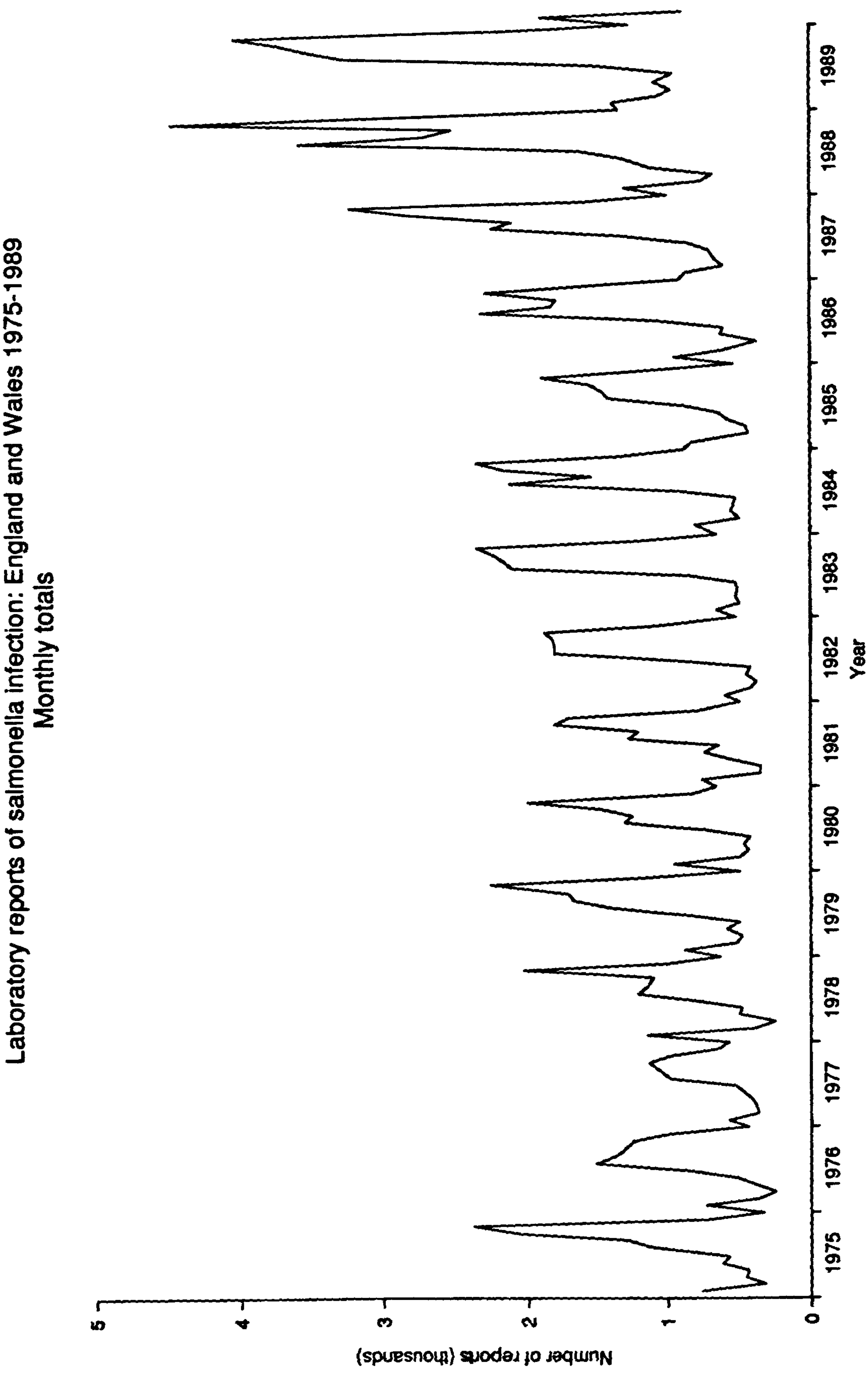


Figure 3.2



Laboratory reports of salmonella infection: England and Wales 1975-1989
Monthly totals
Number of reports (thousands)
0
1
2
3
4
5
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
Year

Notification of food poisoning and Laboratory Reports of salmonella infection
England and Wales 1975-89
Reporting and notification rates per 100,000 population

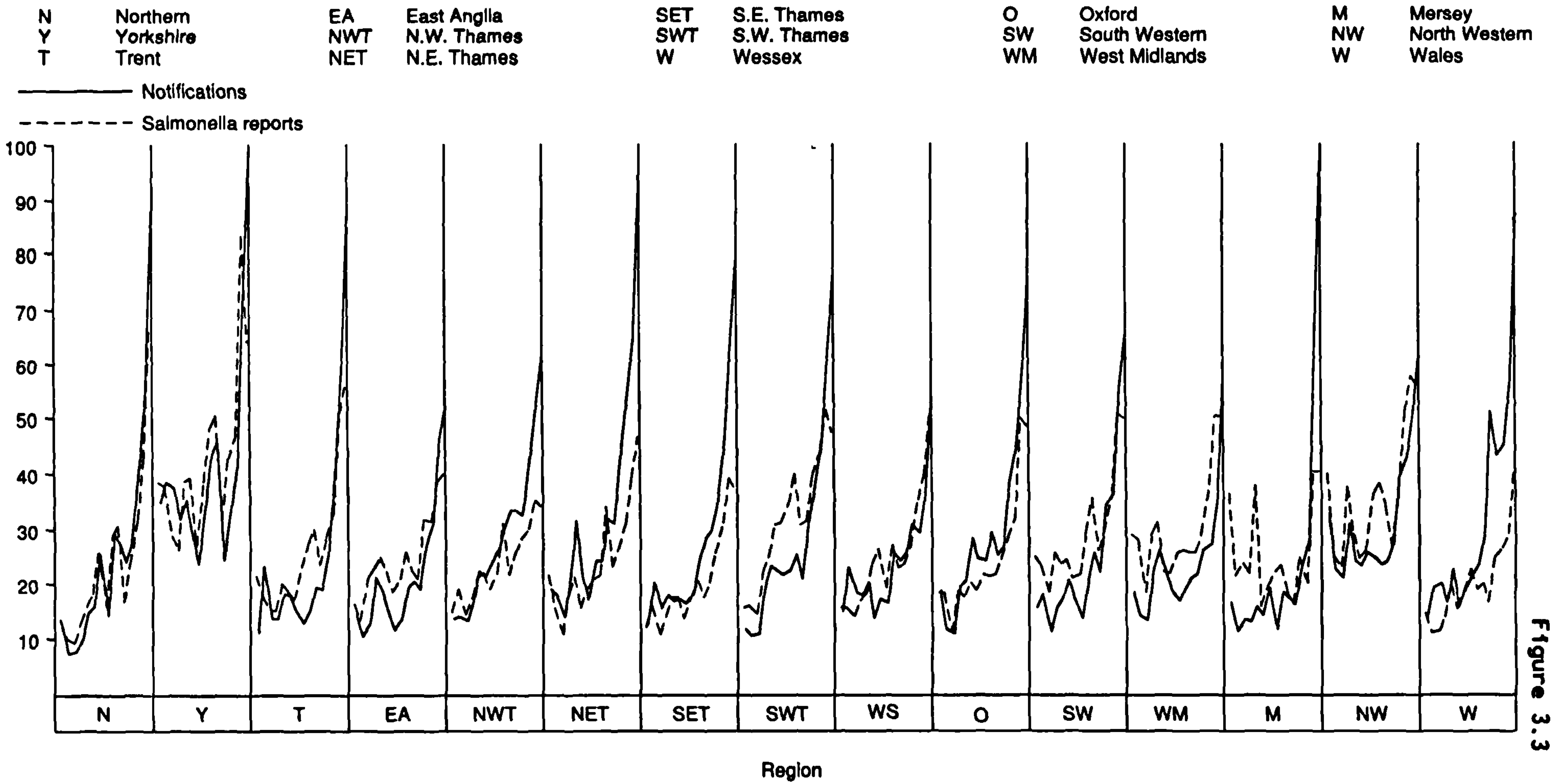


Figure 3.3

increase in rates of 2-3 fold. This was particularly marked in 1988-89 when notification rates continued to rise whereas rates in salmonella reporting tailed off.

To further explore geographical variation, salmonella reporting rates were compared for the three major serotypes (Figure 3.4). Most regions showed increased reporting rates for **S. typhimurium** from the late 1970's to the mid 1980's followed by a decline, however, Northern Region showed a continuing upward trend**. Rates for **S. virchow** were much lower when compared with **S. typhimurium** and **S. enteritidis** and showed little annual change after the late 1970's. Exceptions to this were peaks in reporting in three regions which were the result of reported outbreaks. **S. enteritidis** showed a consistent pattern across all regions with a marked increase in reporting between 1985 and 1986 corresponding with increased incidence of **PT 4** infection.

Age and sex.

There was no significant difference in notification rates between males and females from 1974 to 1989 (Figure 3.5). There were differences between age groups (Figure 3.5); thus, although the notification rate in all age groups approximately doubled from 1974 to 1985 and again between 1985 and 1989, that in children under five years was 2 to 3 times greater (notification rate in males aged 0 to 4 years and 5 to 14 years were consistently higher than in females but this trend was not

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*To explore the possibility that there may be considerable differences in notification rates within a region, trends within Yorkshire were examined in more detail. Rates for West Yorkshire, Humberside and North Yorkshire showed considerable annual variation although West and North Yorkshire increased sharply in 1988-89 compared with Humberside. Within West Yorkshire notification rates in Kirklees and Bradford were consistently higher than the other districts. Bradford, Kirklees and Leeds all increased in 1988 and 1989 but rates in Calderdale and Wakefield remained low indicating the first three districts particularly affected rates overall in West Yorkshire (see Appendix 3d).

To examine the possibility that particular strains of salmonellas may be more prevelant in some areas than others, thus affecting local trends, reporting rates for all salmonella serotypes and **S. typhimurium were compared by region for 1983 and 1988. **S. typhimurium** accounted for half of reports in Yorkshire in 1983 but only about a fifth in 1988 see Appendix 3e). Furthermore, only three phage types (DT 10, 12 and 49a) accounted for half of the reports of **S. typhimurium** in 1983 but for only about a quarter of reports in 1988. Modelling this data showed that there was significantly less **S. typhimurium** DT 10, 12, 49a in 1988 compared with 1983 and that these phage types were particularly associated with Yorkshire region in 1983.

Laboratory reports of selected salmonella serotypes: England and Wales 1975-1989
Reporting rate per 100,000 population for NHS Regions.

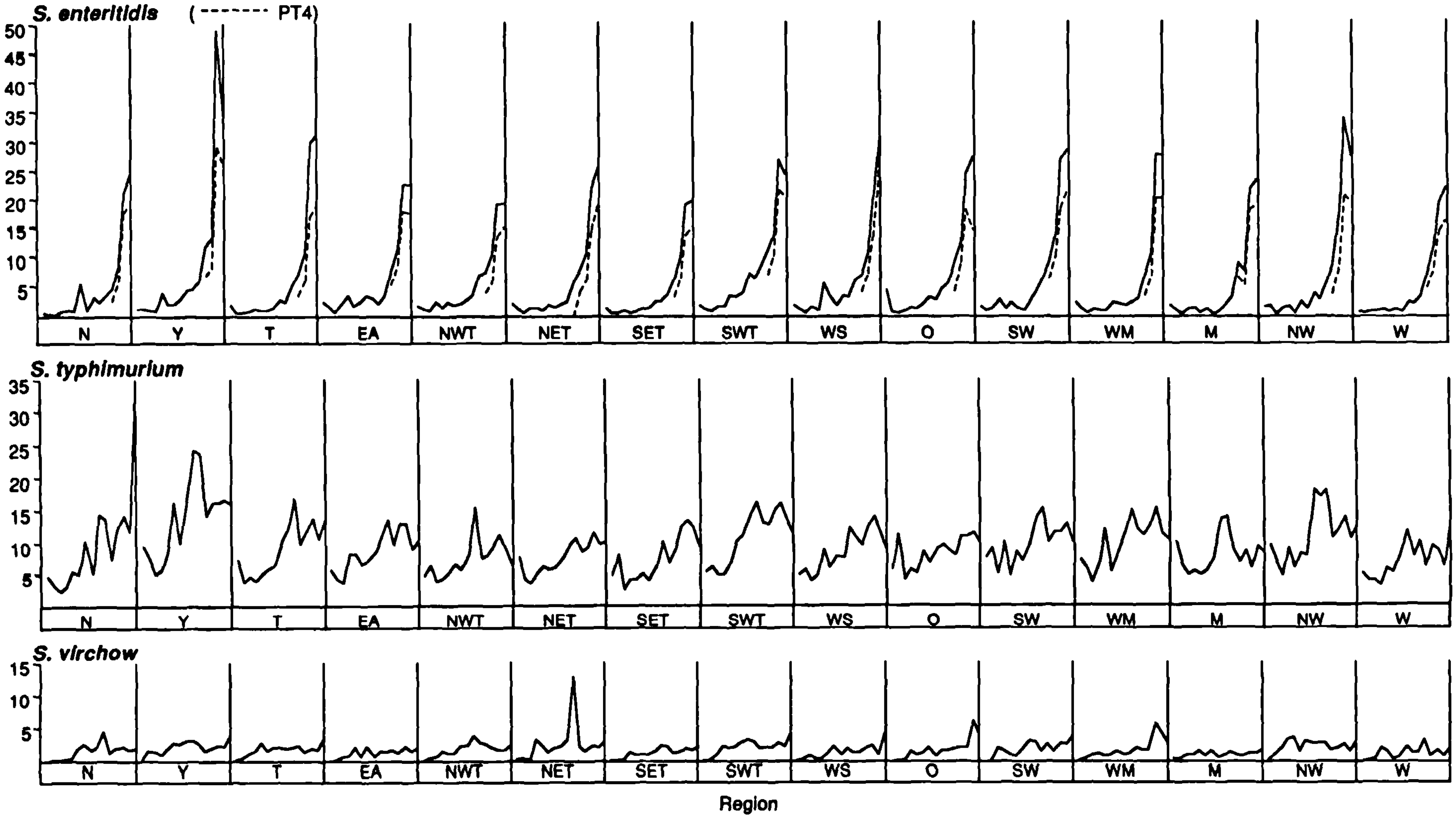
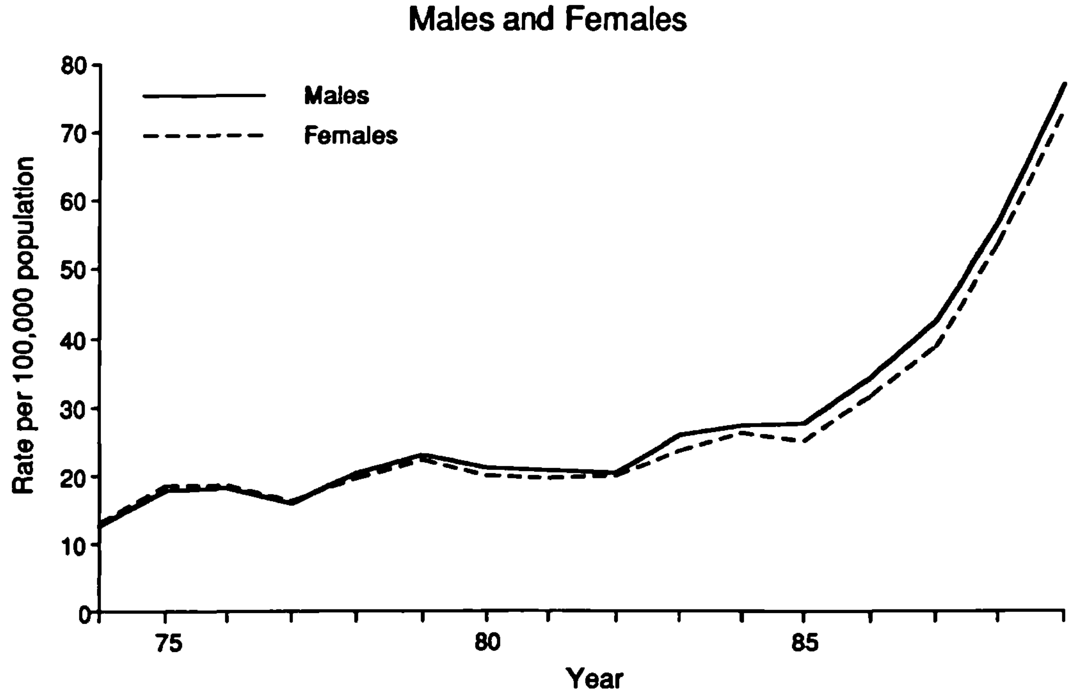
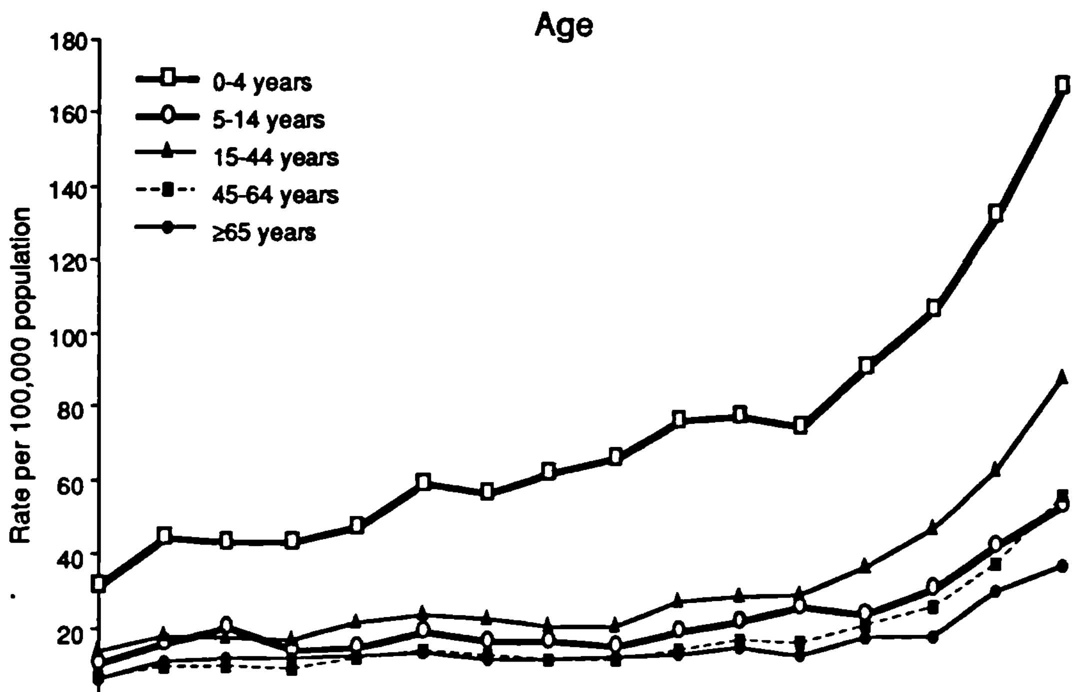


Figure 3.4

Food poisoning notification rates (Formal notifications)
England and Wales 1974-1989





evident in the older age groups). Laboratory data on the age of cases for 1989 showed a similar trend to that of notifications; the rate in the 0 to 4 years age group was 133 which was 2 to 3 times that in other ages (5-14 years, 35; 15-44 years, 48; 45-64 years, 33; ≥65 years, 24).

The ten most common serotypes were compared by age group for 1989 as rates (Table 3.1). For each serotype rates were highest in children aged 0 to 4 years. Reporting of **S. kedougou**, **S. newport** and **S. panama** increased again in the elderly. The possibility that certain serotypes may affect particular age groups warrants further investigation, however, for some of these serotypes numbers of reports were low and trends could be influenced by cases associated with a single outbreak.

Deaths.

From 1960 to 1989, 1,088 deaths from salmonellosis (underlying cause) were registered (annual average 36.2 or 3.5 deaths per 1,000 notifications of food poisoning). Deaths attributed to other causes of food poisoning in this period was 61. The annual salmonellosis death rate ranged between 2.8 and 6.5 (per 1,000 notifications) from 1960 to 1985 (annual average 1960-1985: 4.2). However, from 1986 onwards the rate declined and was 1.6 in 1989 (annual average 1986-1989: 2.2).

The results of the analysis of laboratory reports were more difficult to interpret since some patients may have been reported before they died and a follow-up report was unlikely, resulting in under ascertainment. Nevertheless, they showed broadly the same trends; salmonella infection was reported in 1,057 patients who died over the 27 year period from 1962 to 1988 (annual average 39.1 or 4.1 deaths per 1,000 laboratory reports). There was also a decline in the annual rate (per 1,000 laboratory reports) from an annual average of 5.2 between 1962 and 1985 to 2.7 in the period 1983 to 1989.

Information on the age and sex of persons who died was obtained for the period 1975 to 1989. Over this period 704 deaths were notified with salmonella infection given as the underlying cause. There were fewer deaths in males than in females but there were some differences between age groups. Thus the rate was slightly elevated in young children, mainly neonates. The rate also increased with age in adults over 45 years and most sharply in those aged 75 years and over (Table 3.2).

Table 3.1

Ages of Confirmed Salmonella Infections (Ten Most Common Serotypes)

Faecal Isolations Reported to CDSC by Laboratories in England and Wales and Reporting Rate per 100,000 Population (in brackets) : 1989

Serotype	Age group (years)									
	0-4		5-14		15-44		45-64		≥65	
S. enteritidis	2,086	(65.54)	1,212	(19.43)	5,483	(24.88)	1,945	(18.03)	1,042	(13.44)
S. typhimurium	1,179	(37.04)	593	(9.51)	2,518	(11.70)	779	(7.22)	398	(5.13)
S. virchow	196	(6.16)	117	(1.88)	762	(3.46)	224	(2.08)	88	(1.14)
S. hadar	33	(1.04)	7	(0.11)	145	(0.66)	67	(0.62)	17	(0.22)
S. infantis	54	(1.70)	17	(0.27)	144	(0.65)	52	(0.48)	27	(0.35)
S. newport	78	(2.45)	9	(0.14)	113	(0.51)	37	(0.34)	38	(0.49)
S. heidelberg	44	(1.38)	26	(0.42)	126	(0.57)	41	(0.38)	15	(0.19)
S. kedougou	47	(1.48)	8	(0.13)	82	(0.37)	48	(0.44)	54	(0.70)
S. panama	50	(1.57)	10	(0.16)	67	(0.30)	34	(0.32)	45	(0.58)
S. agona	26	(0.82)	5	(0.08)	85	(0.39)	21	(0.19)	7	(0.09)
All salmonellas	4,249	(133.49)	2,175	(34.87)	10,635	(48.28)	3,614	(33.49)	1,902	(24.55)

A further 2,767 isolations were recorded for which the age of the patient was not stated

Table 3.2

Age and Sex of Registered Deaths where Salmonella Infection was Given as an Underlying Cause of Death

England and Wales : 1975-1989

Period (years)	Age group (years) 0-4*		5-14		15-44		45-59		60-64		65-74		≥75		Total	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
1975-1979	6 (6)	5 (5)	1	-	8	1	15	8	8	11	29	18	29	65	96	108
1980-1984	5 (3)	5 (2)	2	-	3	6	18	6	13	7	37	18	42	78	120	120
1985-1989	2 (2)	4 (2)	1	1	8	5	8	9	7	8	31	22	60	94	117	143
Total	13 (11)	14 (9)	4	1	19	12	41	23	28	26	97	58	131	237	333	371
Annual average rate per 100,000 population	0.06	0.06	<0.01	<0.01	0.01	<0.01	0.07	0.04	0.15	0.12	0.33	0.15	0.89	0.78	0.09	0.10

* neonatal deaths in brackets M = male; F = female

Laboratory reports for the period 1967 to 1988, for which information was available, were explored to examine the association between salmonella infection and death. This indicated that salmonella infection was the attributable cause of death in 708 (71%) of the 1,004 deaths recorded. However, analysis of all laboratory reported deaths with salmonella infection and cases where death was attributed to salmonella infection showed the same decline in death rate from 8.2 and 7.1 respectively in 1968, to 1.9 and 1.5 in 1989.

Non-typhoid salmonella bacteraemia, meningitis and other complications.
In an analysis of serious non-gastroenteritic salmonella infections in the period 1975 to 1989 a total of 3,209 isolations from blood, CSF and other non-gastroenteritic sites were recorded by CDSC (Table 3.3). This gave an average of 214 such infections reported each year or 16.9 for every 1,000 reported isolations. Blood culture was the single most common site of isolation, accounting for 2,589 (81%) of reports (however, those reported with meningitis or other complications probably also had bacteraemia).

On average, 1.4% of persons reported with salmonella infection had a positive blood culture and 1.7% of all isolations reported were from non-gastroenteritic sites. An assessment of differences in the risk of developing a non-gastroenteritic infection is presented in Appendix 3f (3f.i) for specific serotypes.

Table 3.3 shows the age distribution of cases. Expressing the results as a rate revealed that the age groups in which bacteraemia was most commonly reported were infants, young children, and adults aged 65 years and over. Almost a fifth (19%) of infants recorded were neonates. An analysis of "other" infections is presented in Appendix 3f (3f.ii).

Serotypes reported

Although about 200 serotypes are reported each year to the CDSC, only 35 serotypes were recorded in the annual "top ten" over the period 1962 to 1989 (see Appendix 3g).

Influence of selected serotypes on reported trends.
Since 1960 an increasing proportion of reports have been due to

Table 3.3

Laboratory Reports of Isolates from Blood, CSF and Other Non-Gastroenteritic Sites

England and Wales : 1975-1989

Age Distribution

Site	Age group (years)							Total
	<1*	1-4	5-14	15-44	45-64	≥65	Not stated	
Blood positive	184 (30)	161	126	640	438	896	144	2,589
rate†	1.978	0.439	0.123	0.202	0.265	0.791		0.348
CSF positive	47 (15)	4	1	4	4	4	2	66
rate†	0.505	0.011	0.001	0.001	0.002	0.004		0.009
Other	12 (5)	17	32	156	112	175	50	554
rate†	0.129	0.046	0.031	0.049	0.068	0.155		0.074
Total	243 (47)	182	159	800	554	1,075	196	3,209
rate†	2.613	0.497	0.155	0.252	0.335	0.949		0.431

* (neonates shown in brackets)

† expressed as an annual average rate per 100,000 population (based on 1982 population estimates)

serotypes other than **S. typhimurium** which predominated in the 1950's (McCoy, 1976). Less than 40% were of other serotypes in 1962 compared with between 60% and 76% over the period 1969 to 1981 and 92% in 1990.

A number of serotypes, which occurred as a series of waves, appear to have particularly affected annual trends. These waves corresponded with peaks in salmonella reports in the period 1962 to 1981 when reports of **S. typhimurium** infection remained low at about 2,500 per year (Figure 3.6). Thus peaks in 1969 to 1971, 1973, 1975, 1978 to 1979 and 1983 to 1984 may be attributed to increased reporting of one or more serotypes in each case. An increase since the early 1980's was associated with reporting of both **S. typhimurium** and **S. virchow**. Whilst the current peak (1988-1990) has been particularly associated with a dramatic rise in the number of reported cases of **S. enteritidis**.

Some serotypes including **S. enteritidis**, **S. typhimurium** and **S. virchow** have been reported over relatively long periods. Others, including **S. agona**, **S. hadar** and **S. panama**, were first recorded in the 1960's, peaked, then fell off again to a low level but have remained as important causes of salmonellosis and in some cases showed subsequent peaks. These serotypes are considered in more detail in Appendix 3h.

Infection acquired abroad

Analysis of reports to CDSC for 1989 showed that at least 3,282 persons with confirmed salmonella infection had been outside the UK either when their symptoms started or within a short time of returning to the UK. This represented 13% of the total number of salmonella reports received that year and was less than the proportion recorded by DEP.

Place of visit

Most persons (56%) had visited countries within the EC (Table 3.4). Over three-quarters of these had visited Spain including the Canary Islands and the Balearic Islands. Most of the remaining cases had visited France, Greece and Portugal. A further 329 (10%) of cases went to other European countries, principally Turkey, Yugoslavia and Gibraltar, Malta or Cyprus.

Visits to Africa accounted for 16.5% of cases; three quarters to North

Annual totals of selected salmonella serotypes
Laboratory reports: England and Wales 1962-1989

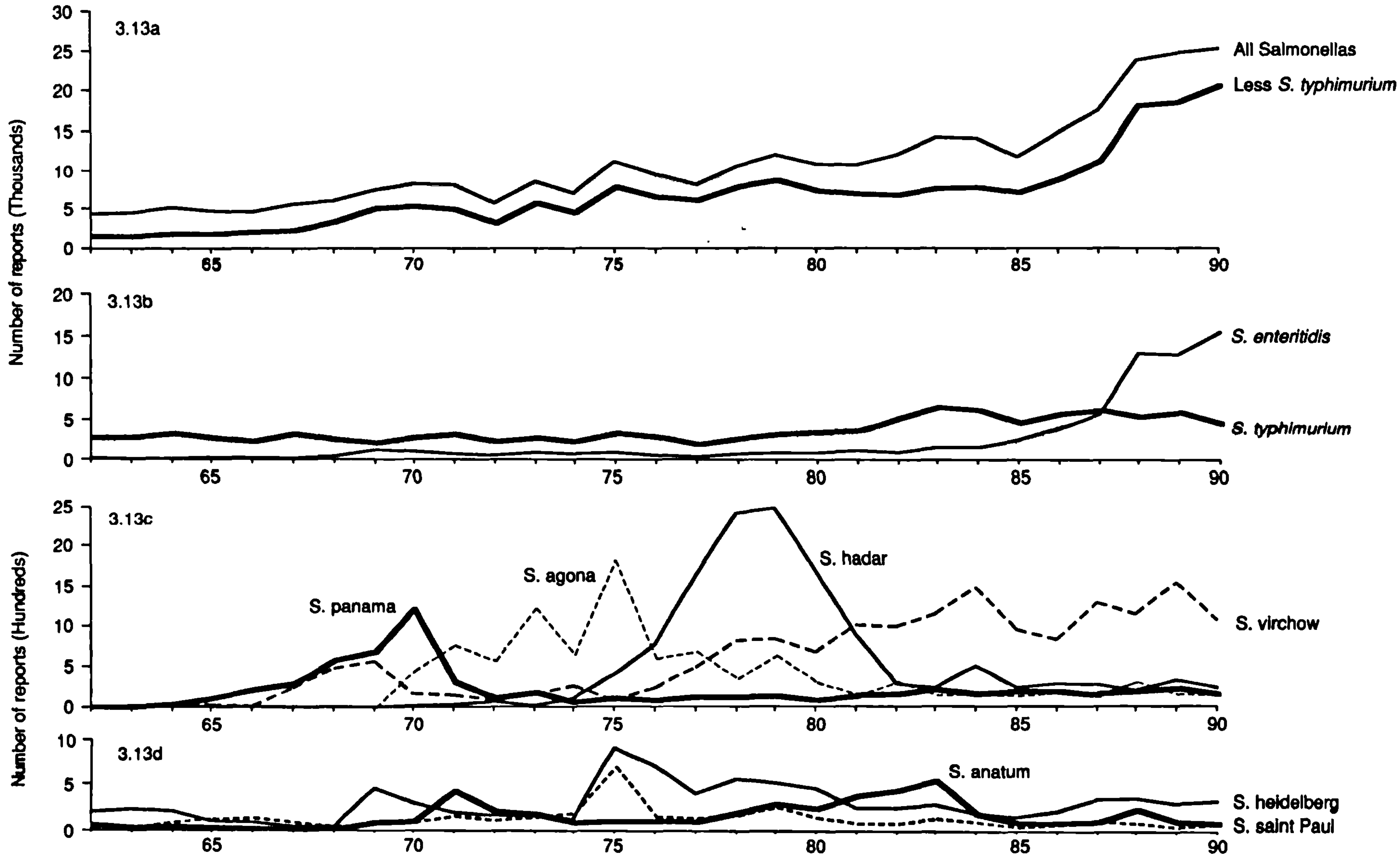


Figure 3.6

Table 3.4

Salmonella Infections in Individuals Returning to England and Wales from Abroad in 1989

Place of Visit and Infection Rates per 100,000 Visits

Location of visit	Salmonella enteritidis	Salmonella typhimurium	Salmonella virchow	Other salmonellas	Total	Visits by UK residents (1,000s)	Infection rate per 100,000 visits
European Community countries	1,134	253	205	238	1,830	22,423	8.96
Other western Europe	111	57	23	101	292	3,704	7.88
Eastern Europe	22	8	-	7	37	323	11.46
North Africa	167	42	32	157	398	387	102.84
Rest of Africa	15	16	8	105	144	367	39.24
Middle East	7	6	3	6	22	226	9.73
Asia	29	57	34	204	324	707	45.83
Australia and New Zealand	1	2	-	7	10	249	4.02
North America	10	3	1	13	27	2,218	1.22
Central and South America	3	8	2	22	35	96	36.46
Commonwealth Caribbean	10	11	-	40	61	276	22.10
Other, not stated, or cruise	60	19	4	19	102	53	-
Total	1,569	482	312	919	3,282	31,030	10.58

Africa. Tunisia was the country most often recorded but for almost two thirds of cases the specific destination was not mentioned. Of the rest of Africa, Kenya and Gambia were the most frequent destinations.

Ten per cent of cases had been to Asia; 179 (55%) of whom visited the ISC. Thailand, Malaysia and Hong Kong were the other destinations mentioned. Small numbers of visits to other destinations included 61 to the Caribbean. A further 102 persons had visited some other location not classified above, had been 'abroad' or had been on a cruise.

Comparison of risk of infection by country.
Although the number of infections was far higher for some countries than for others, this was not an accurate indication of the risk of becoming infected. Therefore rates derived from the number of visits to each country by UK citizens were compared (Table 3.4). On average rates of infection were very low for North America and Australasia (≤5) and low (6-10) for Europe and the Middle East. Higher rates (11-50) were observed for most of Africa, Asia, the Caribbean, Central and South America and very high rates (≥51) for North Africa.

Serotype of salmonella.
The three most common serotypes, **S. enteritidis** (47%), **S.typhimurium** (15%) and **S. virchow** (10%), accounted for 72% of all reports received. The remaining 28% were due to 111 other serotypes, many of which were reported only once, and a small number where the serotype was not specified or not reported.

S.enteritidis was the most common serotype reported (48% of reports) and was the most common serotype in visitors to Europe, N America and N Africa and predominated as the cause of infection in visitors to Spain and Portugal. **S. typhimurium** was the most common serotype identified from visitors to the Benelux countries, Turkey and India, although it was frequently isolated from visitors to several other areas. **S. virchow** was the single most common serotype in visitors to Thailand, and was also common in visitors to several other countries.

Some less common serotypes appeared to be particularly associated with certain countries or areas. At least half of reports of **S. ohio, S. derby, S. brandenburg, S. muenchen, S. panama** and **S. gold-coast** were recorded in persons who had visited Spain and the Balearic Islands. Five serotypes, in addition to **S. enteritidis**, were associated with visits to North Africa and either all or most **S. corvalis**, **S. kentucky**, **S. zanzibar** and **S. colypark** infections were recorded in visitors to North Africa. Both cases of **S. weltevreden** had visited East Africa and most isolates of **S. bareilly** were from visitors to India.

Seasonal variations

The proportion of all salmonella infections which were acquired abroad (3,282 reports in 1989) and the rate of infection was lowest in the first quarter of the year (7.2%; 4.1 per 100,000 visits), increased to a peak in the third quarter (2nd Quarter: 12.9%; 9.5 per 100,000 visits. 3rd Quarter: 14.7%; 14.8 per 100,000 visits) and declined in the fourth quarter of the year (10.3%; 7.9 per 100,000 visits). Peaks in June, and August and September corresponded with holiday periods. Visits to Europe, the Mediterranean and North Africa contributed mainly to the Summer peak (Figure 3.7). Visits to the ISC and North Africa maintained reporting during the early part of the year.

Outbreaks I. Place of outbreak

Type of outbreak.

In the period 1960 to 1989, CDSC received reports of 17,803 outbreaks of salmonellosis and bacterial food poisoning, due to **Clostridium perfringens**, **Staphylococcus aureus** and **Bacillus sp.** Of these 12,064 (68%) were family and 5,739 (32%) were general outbreaks. Salmonella infection accounted for 86% of reports. However, whereas 96% of family outbreaks were due to salmonella infection the proportion ascribed to general outbreaks was lower (63%). Peaks in recorded outbreaks were observed between 1970 and 1973, and in 1989. The annual numbers of family outbreaks ranged considerably and the overall trend since 1960 was largely influenced by the reporting of this category (Figure 3.8). The annual numbers of general outbreaks was relatively constant.

Cases associated with outbreaks.

The annual number of cases recorded by CDSC increased steadily from the mid-1960's. This trend was influenced by reporting of sporadic cases as shown by the trends in total and sporadic cases, and the proportion of sporadic cases (Figure 3.9). In contrast the number of cases

Salmonella Infection Acquired Abroad 1989 : Area visited and month of report

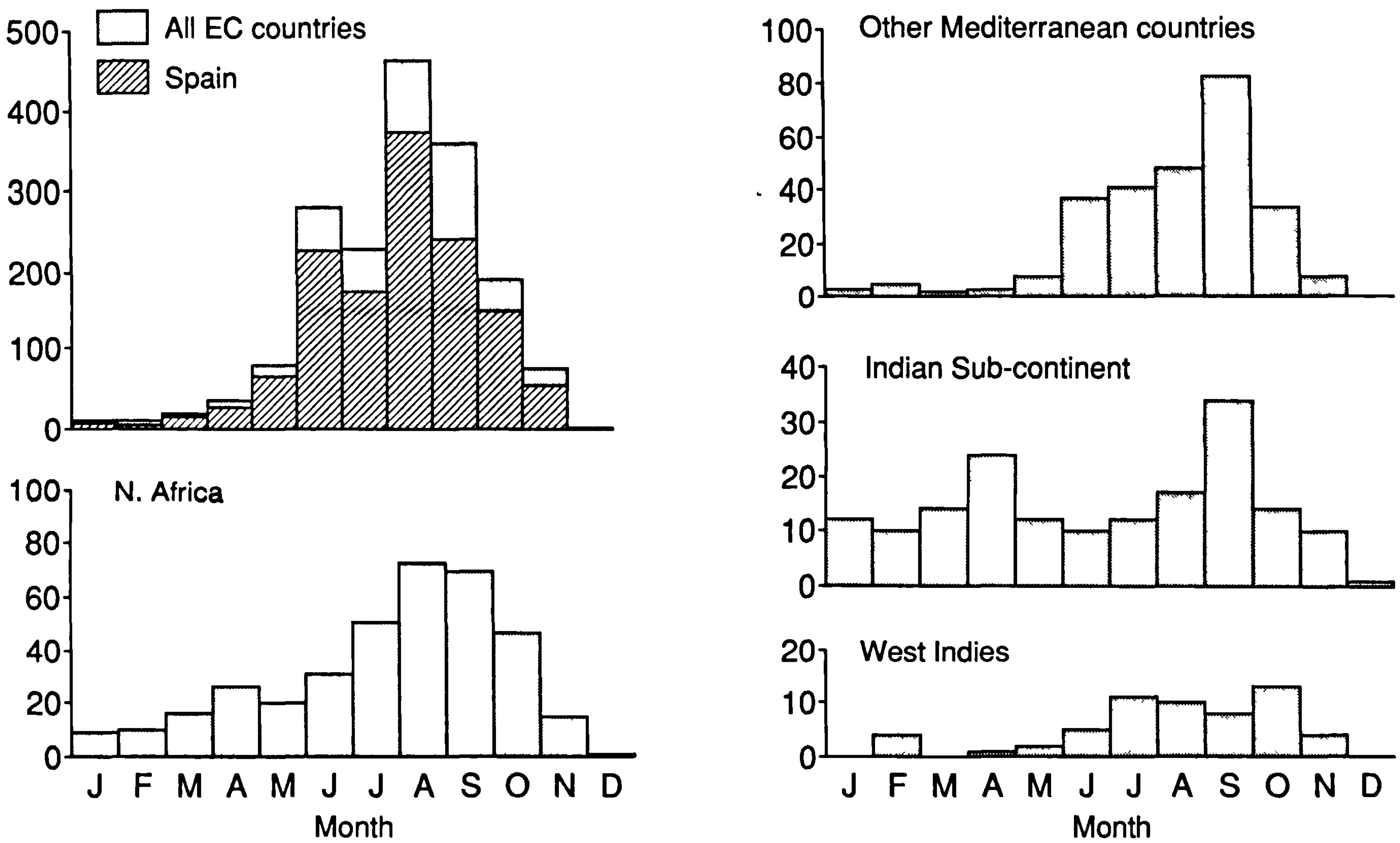


Figure 3.7

Family and General Outbreaks; Laboratory reports to CDSC
England and Wales 1961-1989

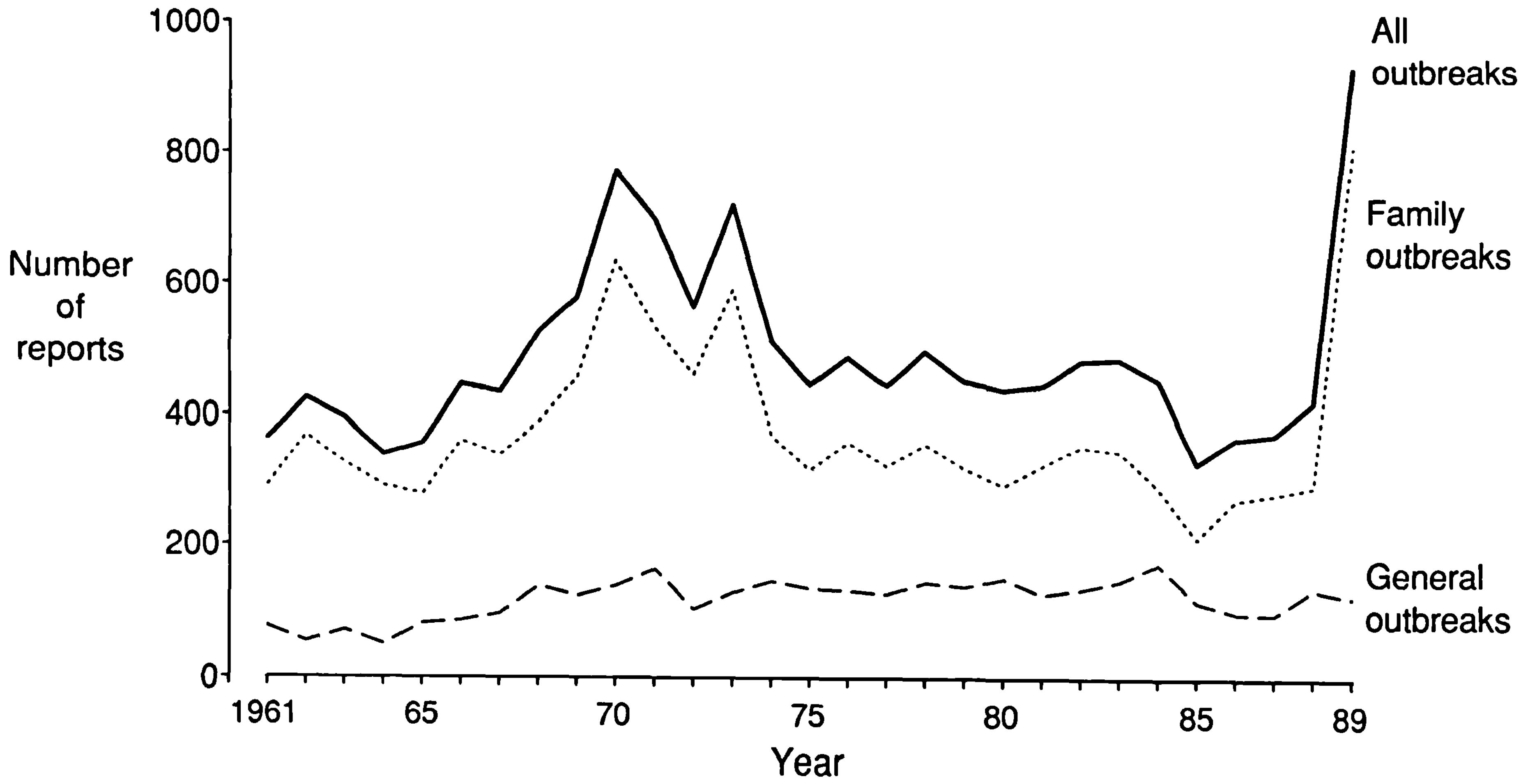
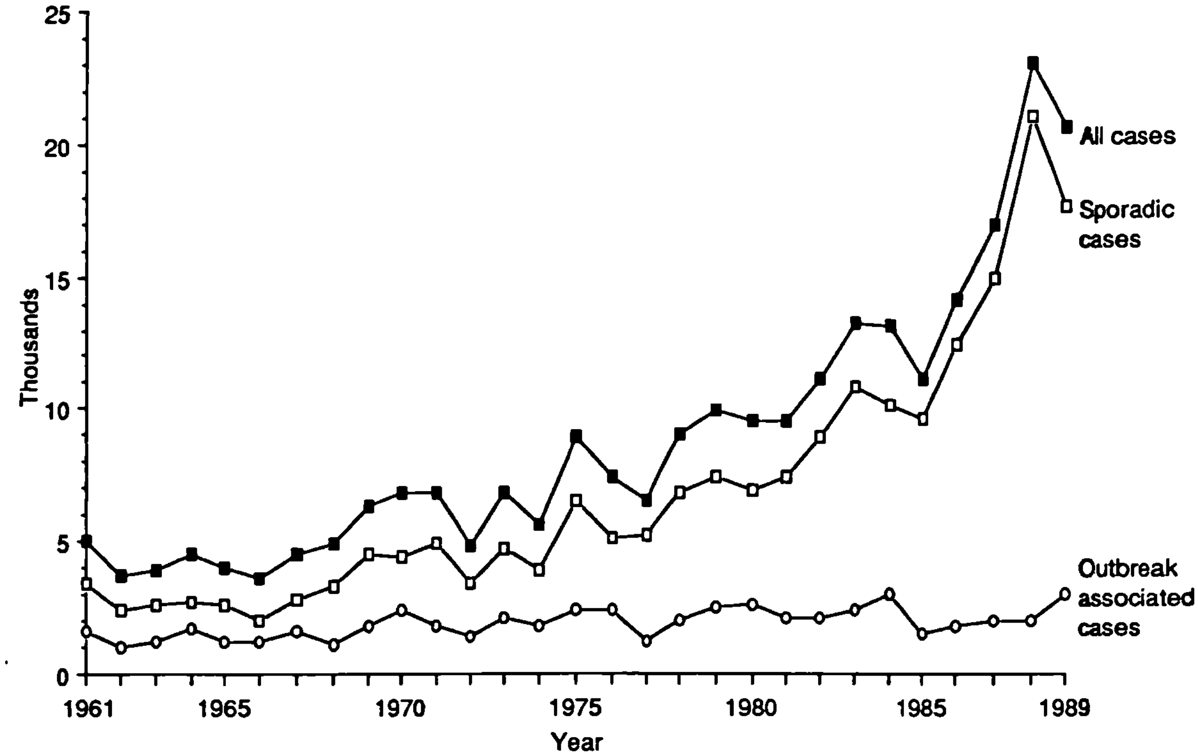
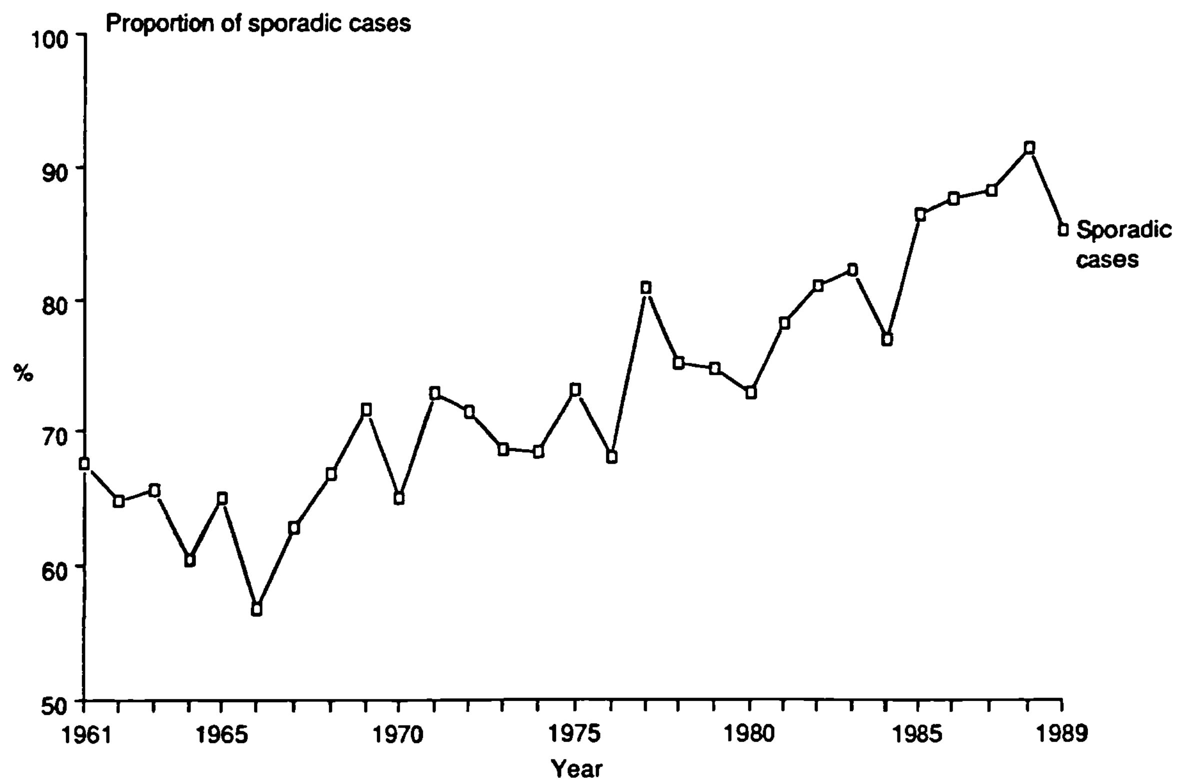


Figure 3.8

Figure 3.9

Sporadic and outbreak associated cases
Laboratory reports to CDSC: England and Wales 1961-89





associated with outbreaks remained fairly constant.

Most common serotypes.

The most common serotype recorded in outbreaks up to 1987 was **S.typhimurium**. This serotype accounted for 47.3% (range 22.5-75.4%) of family outbreaks and 39.4% (range 19.8-66.7%) of general outbreaks reported between 1960 and 1987. The number and proportion of family and general outbreaks due to **S. enteritidis** increased from 1988; this serotype was the most commonly reported cause of salmonella outbreaks in 1988 and 1989 accounting for 52.3% and 56.7% outbreaks respectively.

Family outbreaks.

During the period reviewed family outbreaks accounted for most (63-87%) salmonella outbreaks reported annually. A sharp increase in 1989 from 200 to 300 outbreaks a year to 812 in that year resulted from a change in the way outbreaks were ascertained by CDSC*.

General outbreaks.

General outbreaks accounted for a smaller proportion of salmonella outbreaks recorded (17-37% annually). Over half (55%) of all general outbreaks over the period were associated with restaurants, hotels and and receptions (29%) or with hospitals (26%). Smaller proportions were associated with other situations involving large-scale catering (Institutions, 6%; Schools, 4%; Canteens, 2%) or with farms and dairies (6%) or shops (6%). In a fifth (21%) of outbreaks the place described did not fit any of the above categories or was unspecified.

Trends in place of outbreak reported showed some variation over the period (Figure 3.10). Hospitals were the most frequently recorded category between 1960 and 1976, with peaks in 1968, 1971 and 1974. Thereafter hospital outbreaks declined and was the lowest number recorded in 1989, although outbreaks in other institutions increased slightly in 1988 and 1989. In contrast, salmonella outbreaks associated with eating at restaurants or receptions increased between 1960 and 1979 and has stayed at a relatively high level since.

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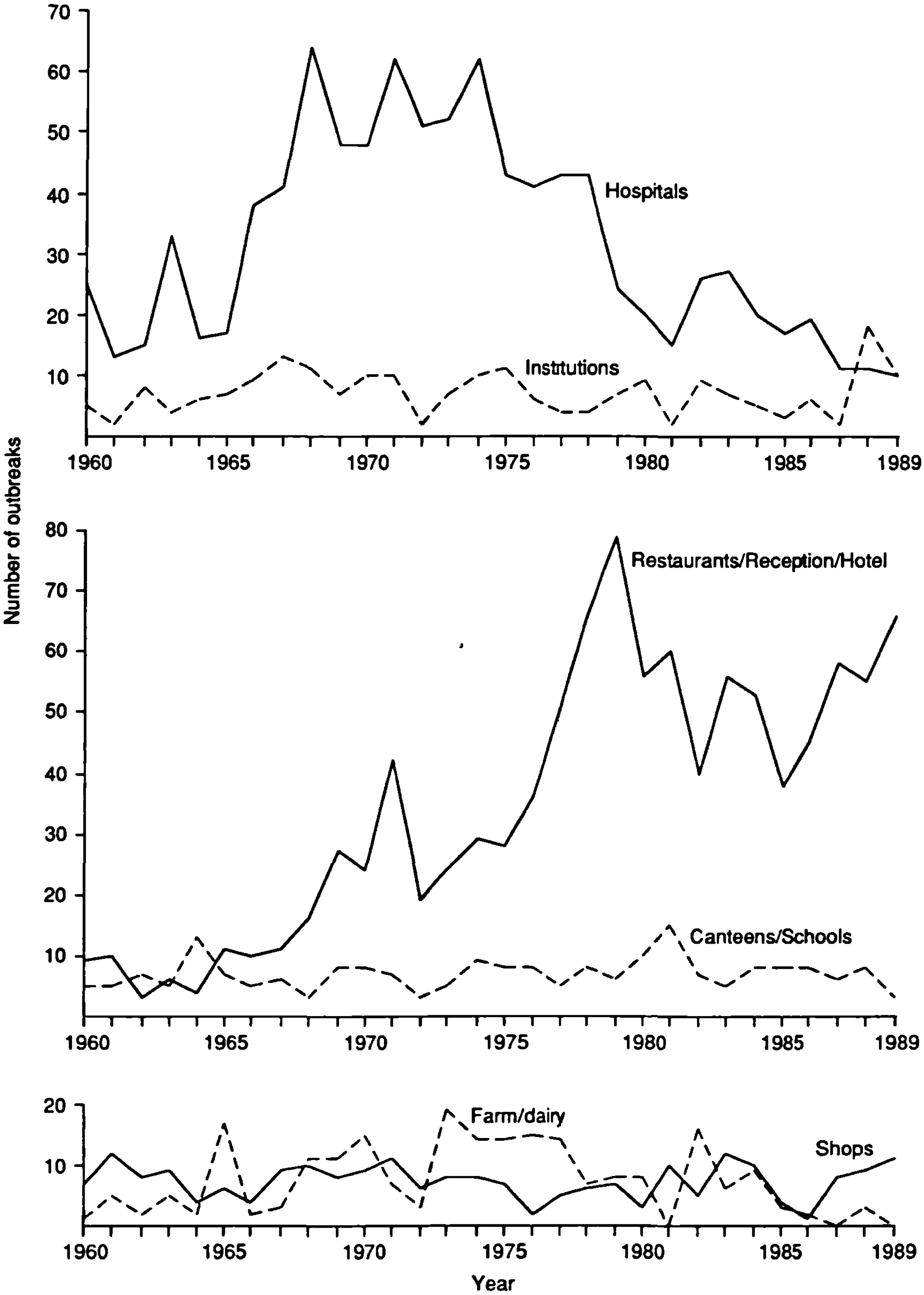
*A new report form, allowing laboratories to record the names of cases was introduced, making it possible to identify family outbreaks by linking family name.

Trends in reporting of salmonella outbreaks: Place of Outbreak
Reports to CDSC: England and Wales 1960-89



An average of seven outbreaks each year occurred in schools or canteens and similar numbers in shops and in farms/dairies. The number of outbreaks implicating farms/dairies has declined since 1982 whereas those associated with shops have increased since 1984.

Outbreaks II. Food vehicles

A total of 3,949 family and general outbreaks for which a suspect food vehicle was mentioned were recorded between 1960 and 1989, accounting for 22% of the 17,803 outbreaks recorded. Salmonellas accounted for 1,746 (44%) of the outbreaks where a suspect food was recorded. Meat and poultry products were mentioned in 2,961 (75%) of outbreaks (Table 3.5). A further 14% were associated with primary agricultural or fishery products which may reach the consumer after only minimal processing. The remaining 10% were due to a variety of single or mixed foods which did not fit into any specific category.

Foods associated with salmonella infection showed some differences when compared with all outbreaks reported (Table 3.5). Thus for meat products, poultry accounted for 63% of salmonella outbreaks compared with 21% of outbreaks due to Clostridium, Bacillus and Staphyloccocal food poisoning. Outbreaks due to milk and dairy products and egg were a significant proportion (18%) of total salmonella outbreaks but accounted for only 1.5% of outbreaks due to other agents recorded.

In only a third of 771 outbreaks between 1985 and 1989, where a suspect food was mentioned, was there supporting microbiological or epidemiological evidence. Supporting evidence was given in only 22% of salmonella outbreaks whereas supporting evidence was obtained in 29% Clostridium, 62% Staphylococcal and 70% Bacillus outbreaks (Table 3.6). There was variation between different food types in the proportion of outbreaks for which supporting evidence was available. Thus supporting evidence was given in only a fifth of salmonella outbreaks due to beef, other meats and egg dishes, in two fifths of pork/ham associated outbreaks and in over half of the outbreaks due to milk and dairy products (Table 3.6).

Poultry.

In the period 1960 to 1989 poultry accounted for 1,150 (29%) of

Table 3.5

Food Poisoning Outbreaks (Where a Suspect Food was Mentioned)

England and Wales : 1960-1989

Food item	Causative agent				Total
	Salmonella	Clostridium perfringens	Staphylococcus aureus	Bacillus species	
Poultry	790	276	74	10	1,150
Beef	66	507	52	7	632
Pork/ham	153	184	94	4	435
Lamb/mutton	8	100	4	1	113
Other or mixed meats, pies, sausages	233	261	117	20	631
Sub-total	1,250	1,328	341	42	2,961
Gravy, sauces	6	45	2	-	53
Milk/dairy products	209	3	14	2	228
Eggs/eggs + other	108	-	8	6	122
Rice	1	-	3	146	150
Seafood	16	6	35	3	60
Other/mixed foods	156	67	78	74	375
Total (food suspect)	1,746	1,449	481	273	3,949

Table 3.6

Comparison of Suspect and Proven* Foods (in brackets) Associated with Outbreaks

England and Wales : 1985-1989

Food item	Causative agent: Salmonella	Causative agent: Clostridium perfringens	Causative agent: Staphylococcus aureus	Causative agent: Bacillus species	Total
Chicken	86 (11)	29 (9)	3 (3)	5 (4)	123 (27)
Turkey	45 (7)	18 (3)	1 (-)	2 (1)	66 (11)
Other poultry	3 (-)	1 (-)	2 (2)	-	6 (2)
Beef	16 (4)	36 (12)	6 (4)	1 (-)	59 (20)
Pork/ham	26 (11)	32 (13)	7 (5)	1 (1)	66 (30)
Lamb/mutton	2 (-)	8 (3)	-	-	10 (3)
Other or mixed meats, pies, sausages	59 (12)	54 (16)	6 (4)	8 (7)	127 (39)
Gravy, sauces	1 (-)	3 (-)	-	-	4 (-)
Milk/dairy products	25 (14)	-	-	1 (1)	26 (15)
Eggs/eggs + other	89 (19)	-	4 (3)	6 (6)	99 (28)
Rice	1 (1)	-	1 (1)	20 (16)	22 (18)
Seafood	9 (1)	7 (-)	3 (1)	2 (-)	21 (2)
Other/mixed foods	55 (13)	25 (5)	14 (6)	48 (30)	142 (54)
Total	417 (93)	213 (61)	47 (29)	94 (66)	771 (249)

* having microbiological and/or epidemiological evidence to support association of food with illness

outbreaks where a food was mentioned (Table 3.5). There was an increase in recorded outbreaks associated with poultry from 1960 to a peak in 1980 which was followed by a decline (Figure 3.11). The trend in reporting was largely influenced by reporting of salmonella outbreaks which accounted for 790 (69%) of outbreaks. Although a number of serotypes were associated with poultry during this period, the peak in 1980 was particularly associated with outbreaks due to **S. hadar.**

Reporting of chicken and turkey associated outbreaks from 1968 showed similar trends with peaks in 1980, however, outbreaks due to turkey thereafter declined faster (Figure 3.11). Salmonella infection was the predominant cause of human illness and was associated with 420 (69%) of chicken and 332 (73%) turkey outbreaks.

Red meats, other processed meats, pies, pasties etc.

A further 1,864 outbreaks were associated with red meats and other meat products and gravies (Table 3.5). The proportion of outbreaks due to salmonella infection varied with the type of meat or product implicated (Figure 3.12). Thus, beef was implicated in 632 (34%) outbreaks but only 66 (10%) of these were due to salmonellosis. A similar result was obtained for outbreaks associated with lamb/mutton and gravies etc. of which only 7% and 11% respectively were due to salmonellosis. In contrast, the proportion of salmonella outbreaks was much higher for pork/ham (35%) and for processed meats, pies,pasties etc (37%).

Milk and dairy products.

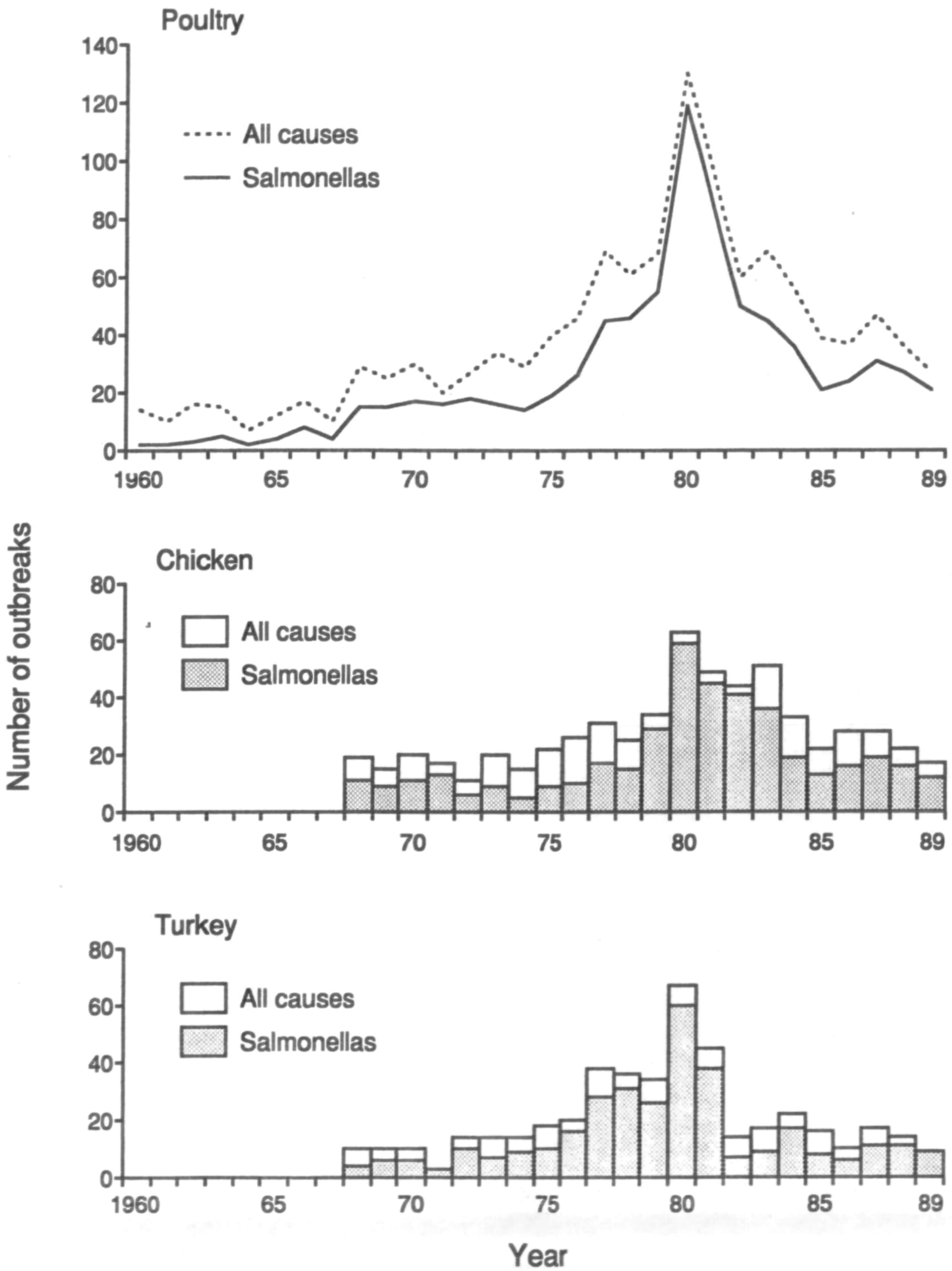
Milk and dairy products accounted for 228, (6%) outbreaks (Table 3.5; Figure 3.13). Most (209) were due to salmonella infection, usually associated with drinking unpasteurised milk; **S. typhimurium** was the serotype most commonly reported. Less than 10 outbreaks a year were reported between 1960 and 1979 but an average of 15 a year was recorded between 1980 and 1985; thereafter numbers again declined.

Egg and egg containing dishes.

Egg, either alone or as a constituent of a food, was reported in 122 (3%) outbreaks and was an unusual vehicle of infection (average: <1 outbreak per year) until 1985. Most, 108 (89%) outbreaks were due to salmonellosis (Table 3.5). Fourteen egg associated salmonella outbreaks were reported between 1985 and 1987. In 1988 the number increased to

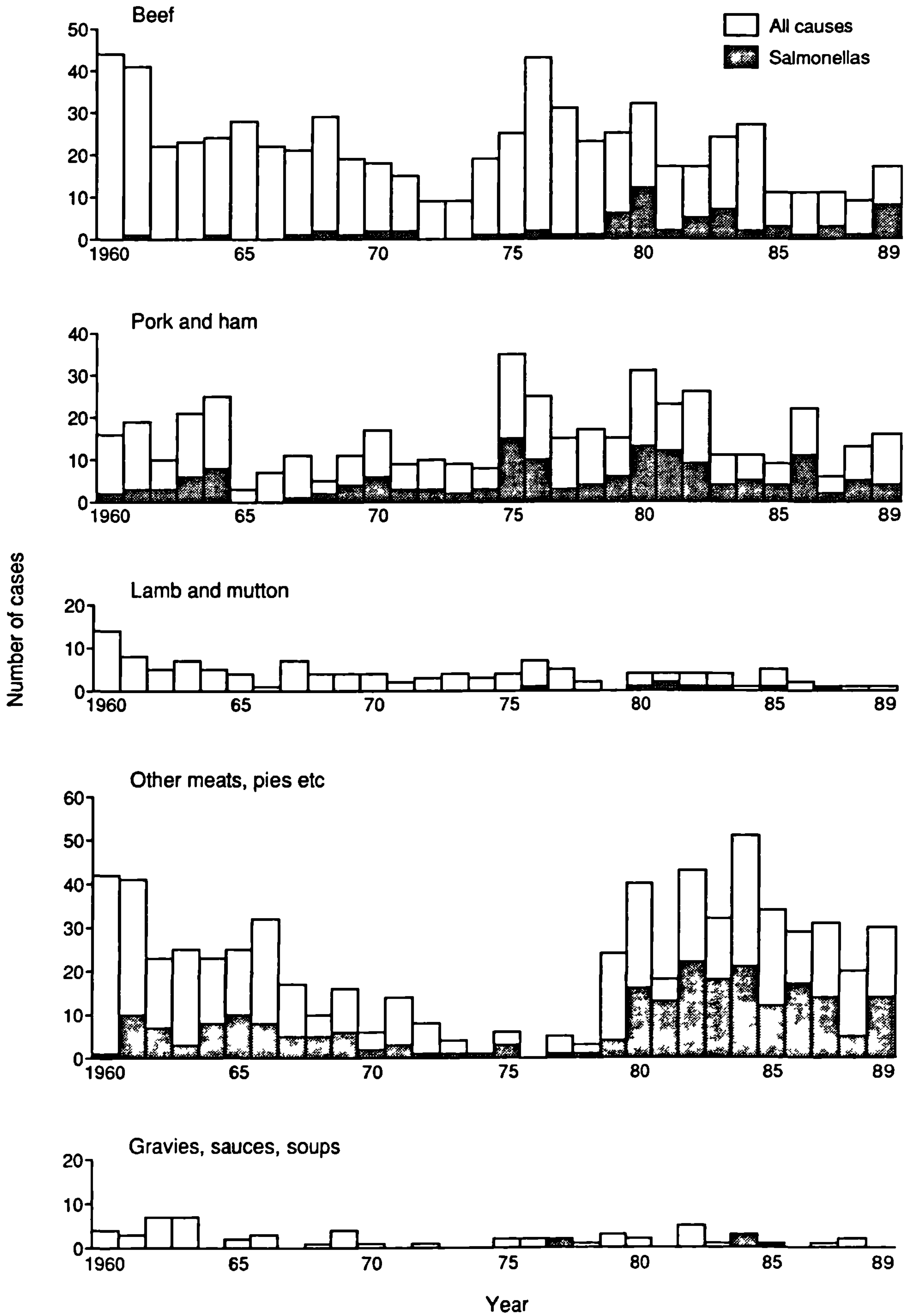
Figure 3.11

Outbreaks Due to Poultry: England and Wales 1960 - 1989
Bacterial Food Poisoning and Salmonellosis

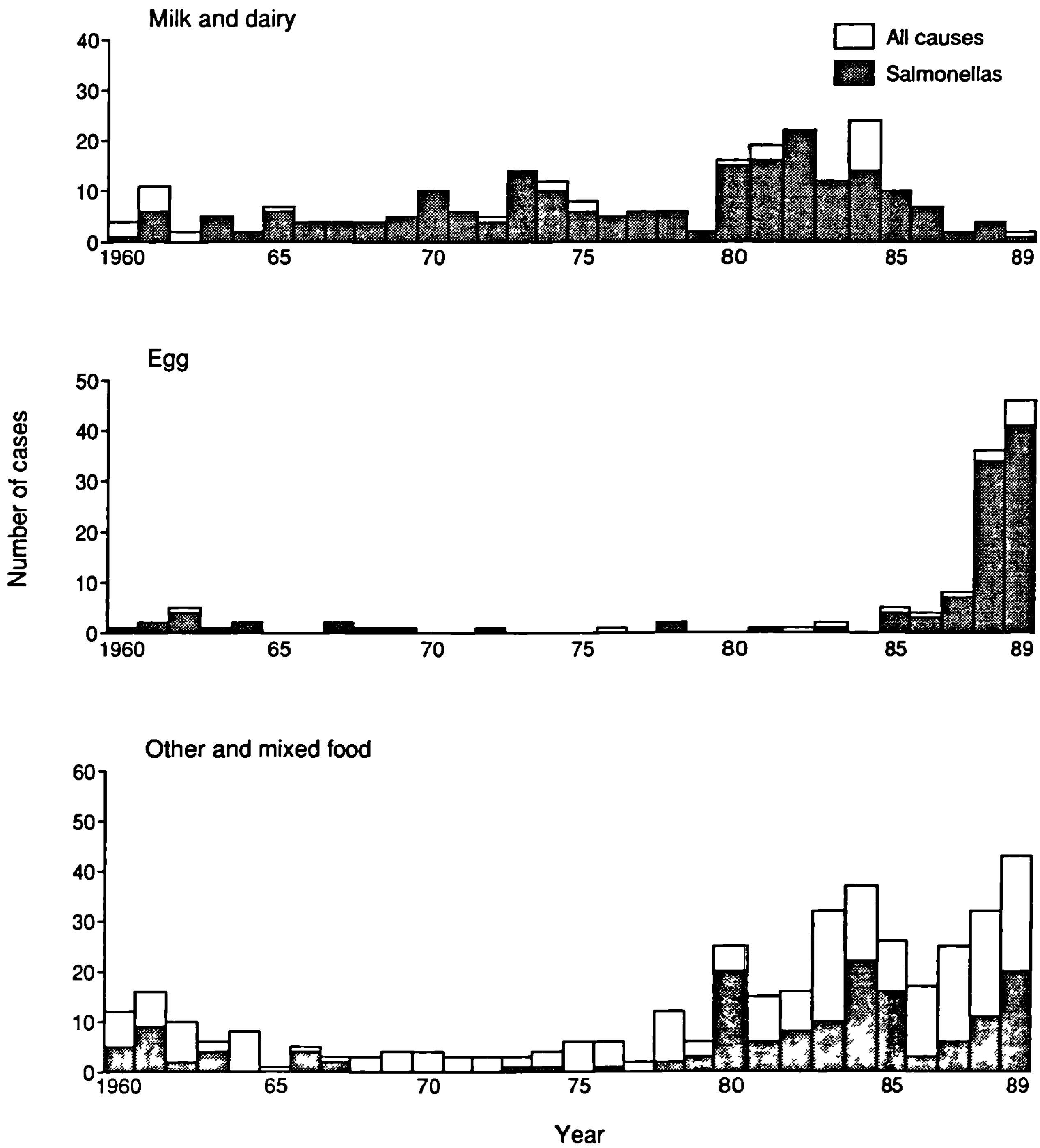


NB. Data on specific food not available until 1967

Outbreaks Due to Red Meats and Other Meats, Pies etc: England and Wales 1960-1989
Bacterial Food Poisoning and Salmonellosis



Outbreaks Due to Other Foods: England and Wales 1960 - 1989
Bacterial Food Poisoning and Salmonellosis



34 outbreaks, and another 41 salmonella outbreaks in 1989. Analysis of reports for the period 1986 to 1989 showed that most (65) egg associated outbreaks were due to **S. enteritidis**, particularly **PT4** (49).

Outbreaks due to **S. enteritidis** associated with poultry and other foods increased between 1986 and 1989 (Table 3.7) although outbreaks due to **S. typhimurium** declined slightly over the same period. To explore the association of **S. enteritidis** with poultry and egg products an analysis was made of the serotypes identified in outbreaks between 1988 and the first half of 1990. In 88 egg associated outbreaks in this period, 13 serotypes and phage types were identified. However, the majority (60) were due to **S. enteritidis PT4**. This compared with at least 24 strains associated with 62 poultry outbreaks (23 due to **S. enteritidis PT4**).

Other and mixed foods.

The remaining 585 outbreaks recorded included 150 in which rice was implicated, one ascribed to salmonella infection, and 60 to seafood (salmonella 16) (Table 3.5); 156 (42%) of the other 375 outbreaks were due to salmonella infection. A wide variety of foods were implicated in these outbreaks including raw foods of vegetable origin such as spices and beansprouts and manufactured foods such as chocolate and yeast based flavouring for savory snacks. Most outbreaks were, however, ascribed to mixed foods and were difficult to categorise.

Manufactured foods.

A total of 294 outbreaks recorded between 1980 and 1989 were associated with UK produced or imported manufactured foods; an average of 29 each year. These accounted for under 5% of the 6,240 outbreaks reported to CDSC during this period. One hundred and thirty-two (45%) outbreaks were due to salmonella infection including seven outbreaks associated with an imported product. Four fifths (107, 81%) of the salmonella outbreaks recorded were due to cooked and processed meats and meat pies. Forty-one of these were due to contaminated meat products where the product was produced locally by small manufacturers, butchers or other shops. The majority occurred in the spring, summer and early autumn, suggesting that poor temperature control was a contributing factor. The remaining outbreaks were associated with a variety of products and are detailed in Appendix 3i.

Foods Associated with S. enteritidis and S. typhimurium Outbreaks

Reports to CDSC : 1986-1989

Salmonella enteritidis
(outbreaks due to PT 4 shown in brackets)

Food item	Year			
	1986	1987	1988	1989†
Eggs	-	2	29 (20)	34 (29)
Poultry	3	11 (4)	9 (7)	12 (9)
Other	6	4	8 (4)	16 (13)
Total	9	17 (4)	46 (31)	62 (51)

Salmonella typhimurium

Food item	Year			
	1986	1987	1988	1989†
Eggs	3	3	5	5
Poultry	17	16	3	6
Other	17	14	12	18
Total	37	33	20	29

† provisional

Outbreaks where the vehicle was unknown or where infection was acquired abroad are excluded.

Infections in animals

Incidents recorded in animals, 1976-1989.

The number of incidents recorded in Statutory Species from 1976 to 1989 are shown in Figure 3.14*. Annual totals were generally between 2,000 and 3,000, but exceeded this in 1976, 1980 and 1989. Cattle were the most commonly recorded species and incidents in cattle were highest in 1976 and 1983. Poultry were the second most commonly reported species and incidents in poultry peaked in 1980 and 1989**. Comparatively, fewer incidents were recorded in sheep and pigs although the number of incidents recorded in both of these species increased over the period reviewed.

Serotypes associated with infections in animals, 1978-1989.

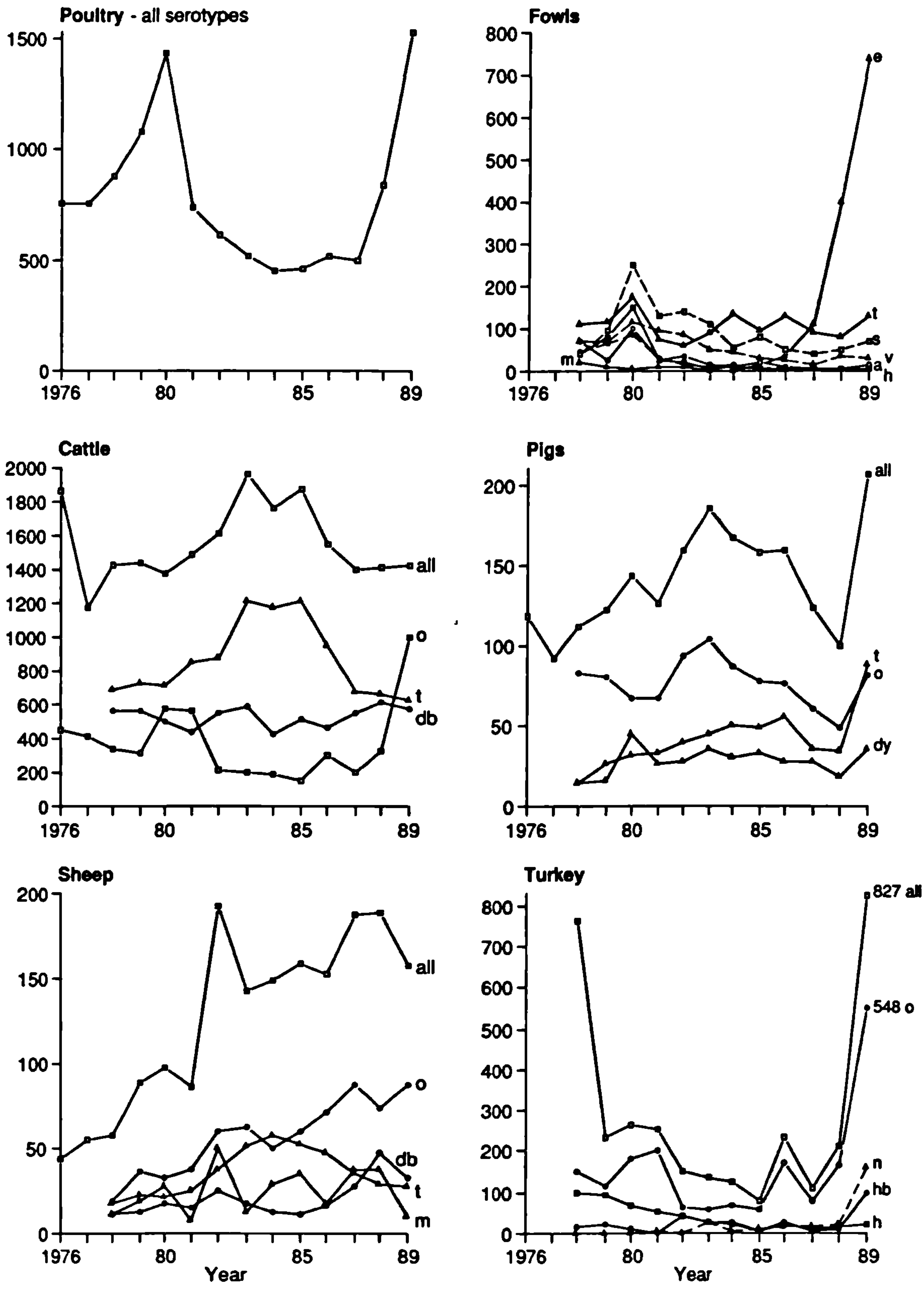
A relatively small number of serotypes were associated with the majority of infections in animals. **S. typhimurium** accounted for a significant number of incidents in all species reviewed except turkeys. Between 12 and 17 different serotypes were recorded in the annual five most common types recorded for cattle, sheep, pigs and poultry. The number of serotypes which were ever recorded in first or second place was limited to 2 to 4 for cattle, sheep and pigs but was greater for chickens (7 serotypes) and turkeys (10 serotypes). The proportion of infections due to the five commonest types varied between animal species. Thus it was consistently about 90% in cattle and 70-80% in sheep. In pigs the proportion rose from 47% in 1978 to 70% in 1985 and thereafter stayed at about the same level. In chickens the proportion has increased (45% in 1978 and 69% in 1989) whilst in turkeys it may be declining (74% in 1978 and 60% in 1989).

The serotypes associated with incidents in animals and poultry since 1975 showed marked differences. There were two peaks in incidents in fowls, in 1980 and from 1987 onwards. The earlier peak corresponded with peaks in incidents due to a number of serotypes (Figure 3.14) whereas the second was due entirely to **S. enteritidis**. A decline in incidents in turkeys between 1980 and 1985 was coincident with a

*Data for the period 1960 to 1975 is summarised in Appendix 3b.

**The increase in 1989 was probably due, in part, to the introduction of statutory testing of flocks.

Common serotypes reported in food animals (UK) under the Zoonoses Orders, 1975 and 1989



Serotypes:							
all	all reports	a	agona	dy	derby	db	dublin
e	enteritidis	o	other serotypes	h	hadar	hb	heidelberg
m	montevideo	n	newport	s	senftenberg	t	typhimurium
v	virchow						

decline in incidents due to S. **hadar** although levels were maintained in 1981 and 1982 by S. **agona**, S. **ohio** and S. **worthington**. Peaks, in 1986 and again from 1988 onwards were associated with a number of serotypes.

A peak in pigs in 1981 corresponded with a peak in S. **derby** and the current increase is associated with S. **typhimurium** as well as other serotypes. A similar picture was presented for sheep, with the overall increase in incidents due to various serotypes although several peaks were apparently due to S. **montevideo**. Cattle presented a different picture; S. **dublin** accounted for a high and fairly constant number of incidents but the trend was most influenced by S. **typhimurium**.

S. typhimurium phage types associated with incidents in animals

Data on the S. **typhimurium** phage types associated with incidents in cattle, sheep, pigs and poultry were examined for the period 1980 to 1989. The ten most commonly reported phage types accounted for the majority of strains typed for each animal species considered. The proportion in cattle due to the ten commonest types was 87%. The remaining typed incidents were due to a wider variety of other recognised phage types in cattle (97 types) than for other animal species (sheep, 46 types; pigs, 41 types, poultry, 66 types). A high proportion of incidents in sheep (79%) and pigs (79%) were also due to the most common phage types. In poultry the proportion was lower (67%). Of the 10 phage types common in cattle nine were also common in sheep and eight in pigs, but only three were identified in poultry.

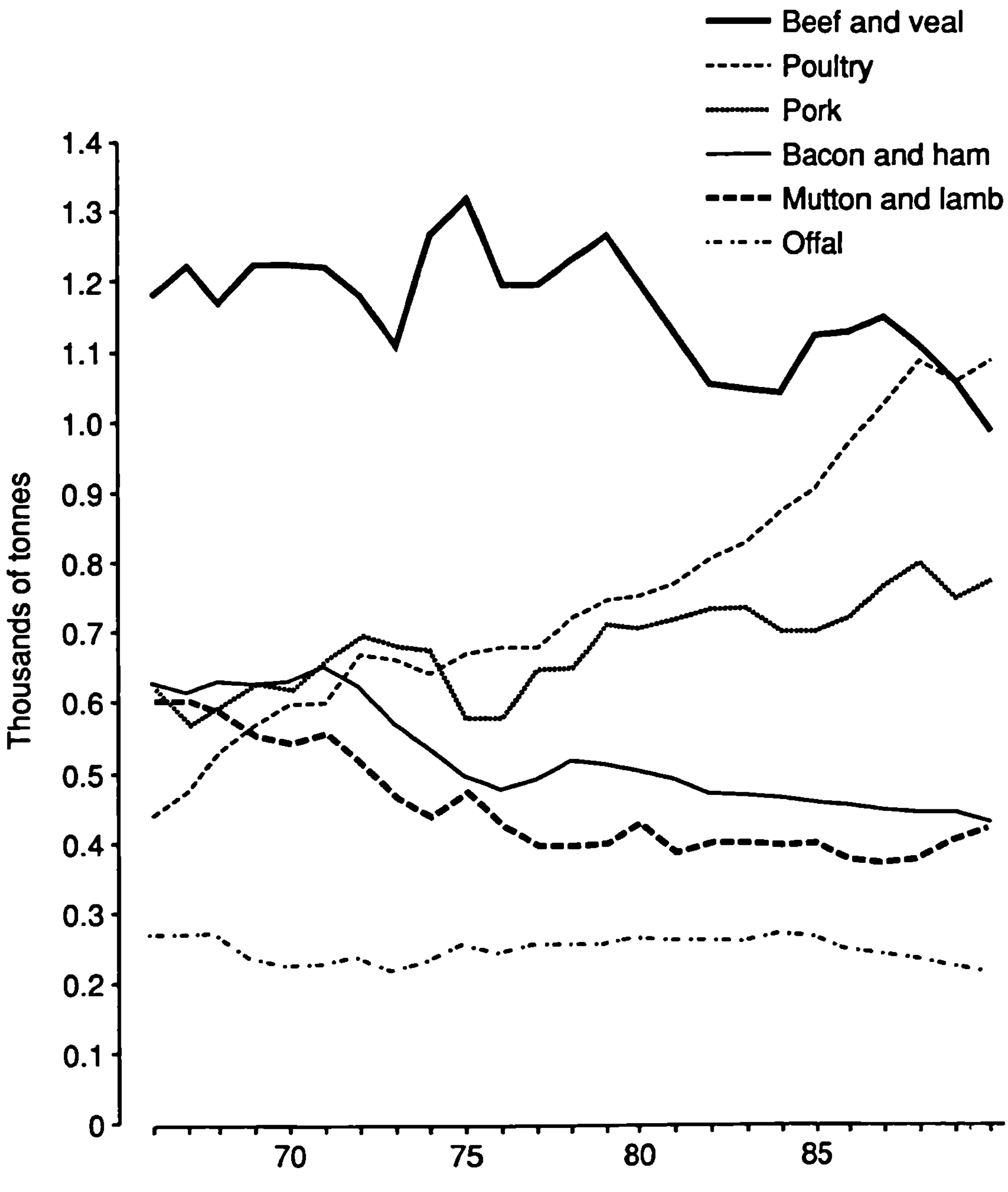
Changing patterns of meat consumption

Since meat and meat products were particularly identified as being associated with salmonellosis, patterns of meat consumption and retailing and home storage were explored to identify factors which may have influenced trends in salmonellosis.

Meat consumption.

Between 1966 and 1989 consumption of beef and veal, and lamb and mutton declined as indicated by estimated meat supplies; consumption of pig meat and offal products remained fairly stable (Figure 3.15). Over this period pork consumption increased but that of bacon and ham declined. Poultry consumption increased steadily, rising by more than 1.5 times.

Estimated UK annual meat supplies by type of meat:1966-1989



Meat consumption patterns were further influenced by the type of meat used (Figure 3.16). In the period 1980 to 1989 home consumption of fresh beef, sheep meat and pig meat declined although this was most noticeable for beef, particularly after 1987*. Household consumption of processed meat was relatively stable for beef and sheep meat but declined for pig meat whilst catering use of these categories of meat increased overall. In contrast there was an increase in all types of poultry meat eaten; in particular, household use of fresh poultry meat rose by over 25% from 1980 to 1988 before it dropped off in 1989.

Patterns in consumption of meat products from 1980 to 1989 also showed marked changes in some categories (Figure 3.17). Consumption of corned meats, canned meats, cooked meats and meat pies, pasties, meat paste, puddings, etc, and delicatessen sausage was unchanged, but consumption of both pork and beef sausages declined. On the other hand there were marked increases in the use of convenience foods including both frozen foods, such as burgers, and other convenience meats, and ready meals.

Seasonality of meat purchase.
The household consumption of meat showed a marked seasonality. Consumption of beef, pork and lamb was lowest in the summer period and highest during the winter months (Figure 3.18). Chicken consumption showed a different pattern and was lowest at the turn of the year, increased in February and then remained high well into early summer.

Meat retailing.
Supermarkets had become the most important outlet for all meat sales by 1990 when compared with 1980 when butchers were the main retail outlet (Table 3.8). This pattern was, however, not uniform for all types of meat. Thus, sales of beef and lamb by 1990 were virtually the same for butchers and supermarkets whereas supermarkets had become the dominant outlets for pork. Supermarkets were the main outlet for bacon and poultry in 1980 and the period up to 1990 saw further increases in the share of supermarket sales of these products.

*This in turn may have reflected public fears associated with BSE after 1987 and caused a further drop when beef consumption was recovering from an earlier decline.

Figure 3.16

Trends in estimated UK consumption of meat by type of meat used: 1980-1989

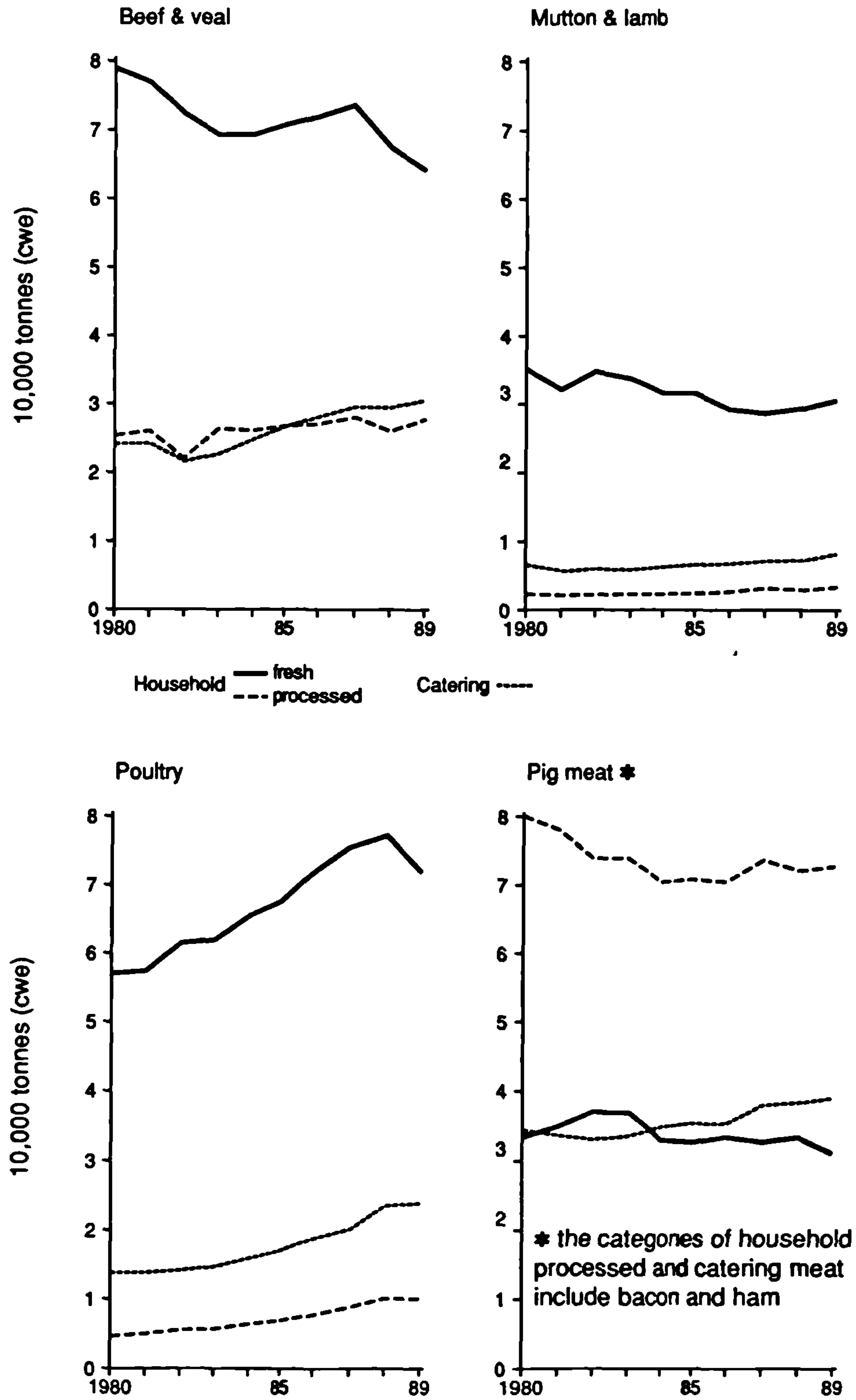


Figure 3.17

Trends in estimated UK consumption of meat by type of meat product: 1980-1989

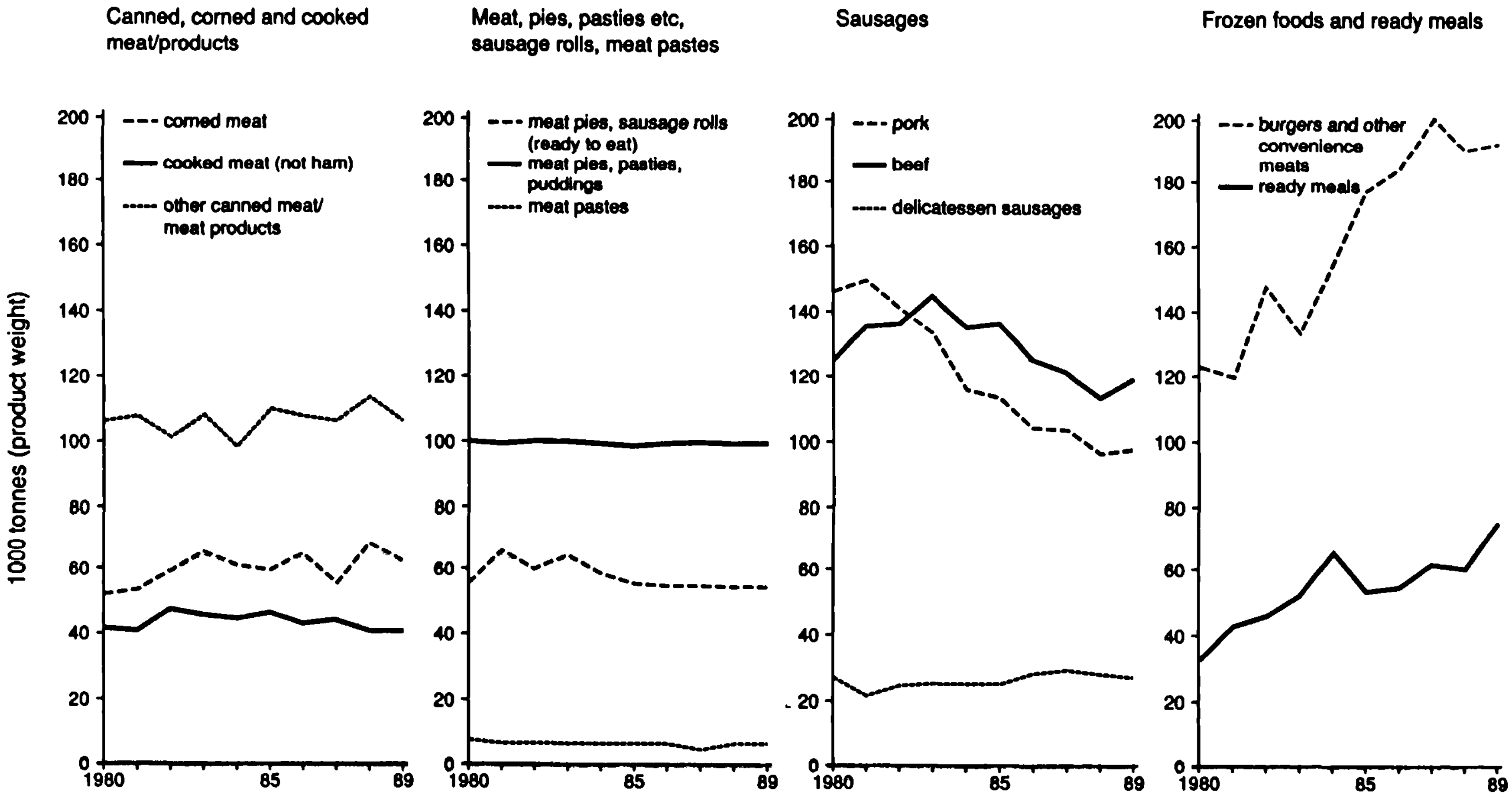


Figure 3.18

Seasonality of household meat purchases:United Kingdom 1988 - 1990
Estimated average 4 - weekly purchases as a percentage of annual averages

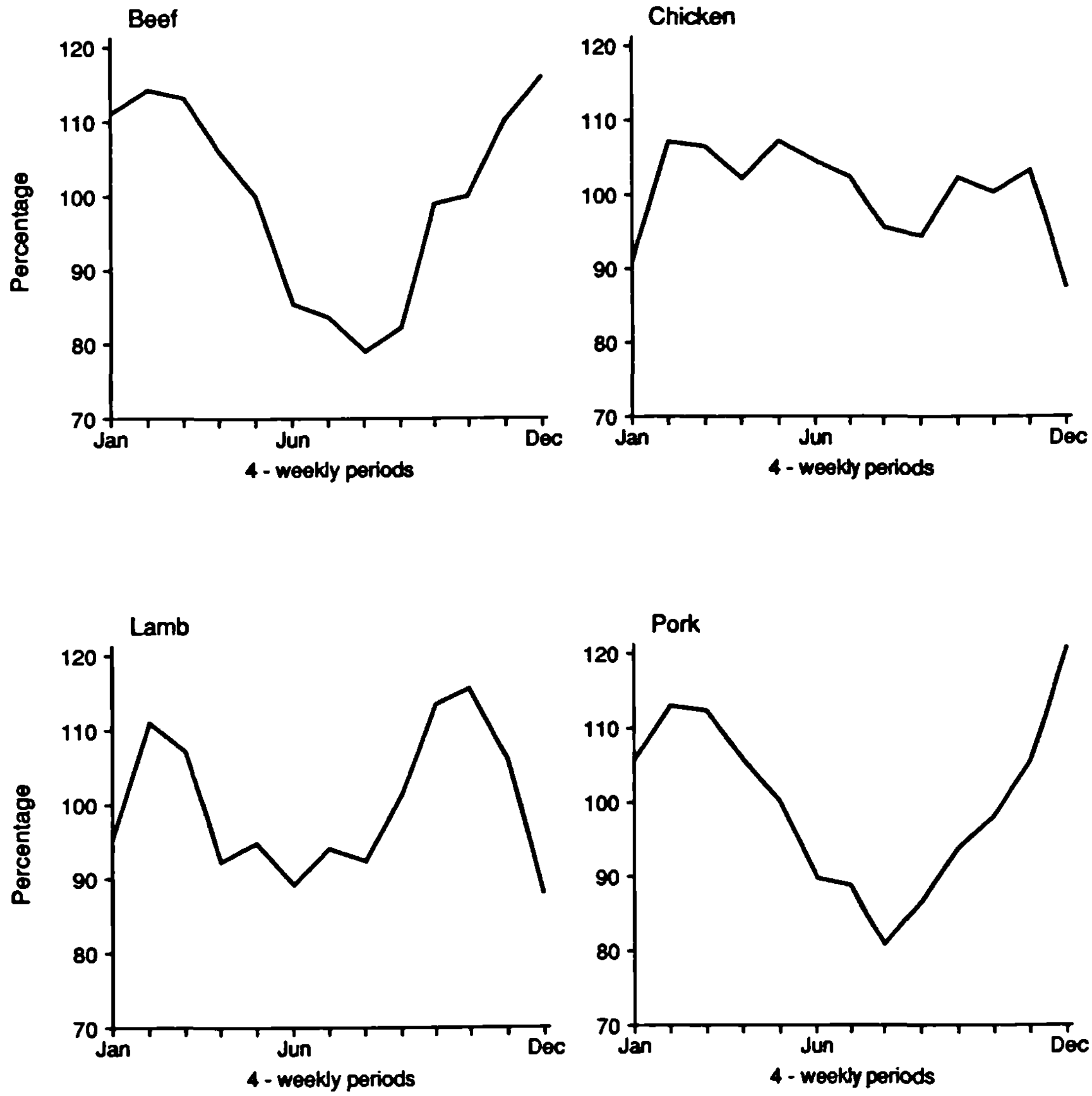


Table 3.8

Proportionate (%) Changes in Place where Meat was Bought

Great Britain : 1980 and 1990

Meat	Year	Butchers	Co-operatives	Supermarkets	Independent grocers	Freezer centres	Other*
Beef	1980	61.0	6.2	19.1	3.0	3.2	7.5
	1990	39.4	5.4	39.6	2.5	3.7	10.4
Lamb	1980	56.4	6.7	22.8	2.5	3.7	7.9
	1990	39.9	5.2	37.7	2.4	3.2	11.5
Pork	1980	53.1	5.2	22.8	3.2	4.3	11.4
	1990	35.9	5.8	42.7	2.1	3.1	10.5
Bacon	1980	23.5	9.7	34.6	14.6	1.4	16.3
	1990	21.8	7.7	48.1	6.2	2.0	14.2
Poultry	1980	23.2	8.1	34.6	4.6	6.2	23.4
	1990	16.6	6.0	52.2	2.6	2.6	14.5

* farm shops, market stalls, variety chain stores

Source: Meat and Livestock Commission (1991)

Influence of annual trends in temperature.

Annual reporting of salmonellosis, and annual average ambient temperature was compared for the period 1962 to 1990 (Figure 3.19). Peaks in annual salmonella totals occurred at intervals of two to four years from 1964 to the mid-1980s, when annual totals rose markedly. This increase was due entirely to reporting of **S. enteritidis** and masked the pattern of peaks and troughs in reported isolations which re-appeared when **S. enteritidis** was removed. Comparison of salmonella reporting trends with annual average temperature showed only some peaks corresponded. However, since annual average temperatures may be strongly influenced by occurrence of a very cold winter and salmonella reporting showed a marked, seasonal summer peak (Figure 3.2), a more valid comparison was with annual average summer temperatures for periods including June, July, August and September (JJAS). The trends observed exhibited a marked similarity in the occurrence of peaks and troughs between summer temperature and trends in reporting of all salmonellas up to 1985, and all salmonellas excepting **S. enteritidis** over the whole period.

Validity of association between temperature and salmonella reporting.
A significant association was demonstrated between annual average summer temperature (JJAS) and all salmonellas for the period 1962 to 1984 (t_{20} = 3.46; P = 0.002) and all salmonellas less **S. enteritidis** for the full 29-year period (t_{26} = 3.39; P = 0.002), although there was no association between annual average temperature and salmonella trends (Table 3.9). Removing **S. typhimurium** from the salmonella total had no effect (P = NS) and when removed with **S. enteritidis** weakened the association (t_{24} = 2.29; P = 0.03)*.

No association was demonstrated between summer temperature and trends in reporting of either **S. enteritidis** or **S. typhimurium** or ten other serotypes reported most frequently in the period reviewed. The results suggested that the effect of temperature was a combined effect of the four summer months (JJAS) although this was likely to have been particularly influenced by the temperatures in July and August.

*Generally all models except that where S. enteritidis and S. typhimurium were excluded showed a good fit, and in no model did outlier observations exert a significant effect.

Average annual and summer temperatures and annual totals of salmonella reports: England and Wales 1962-1989

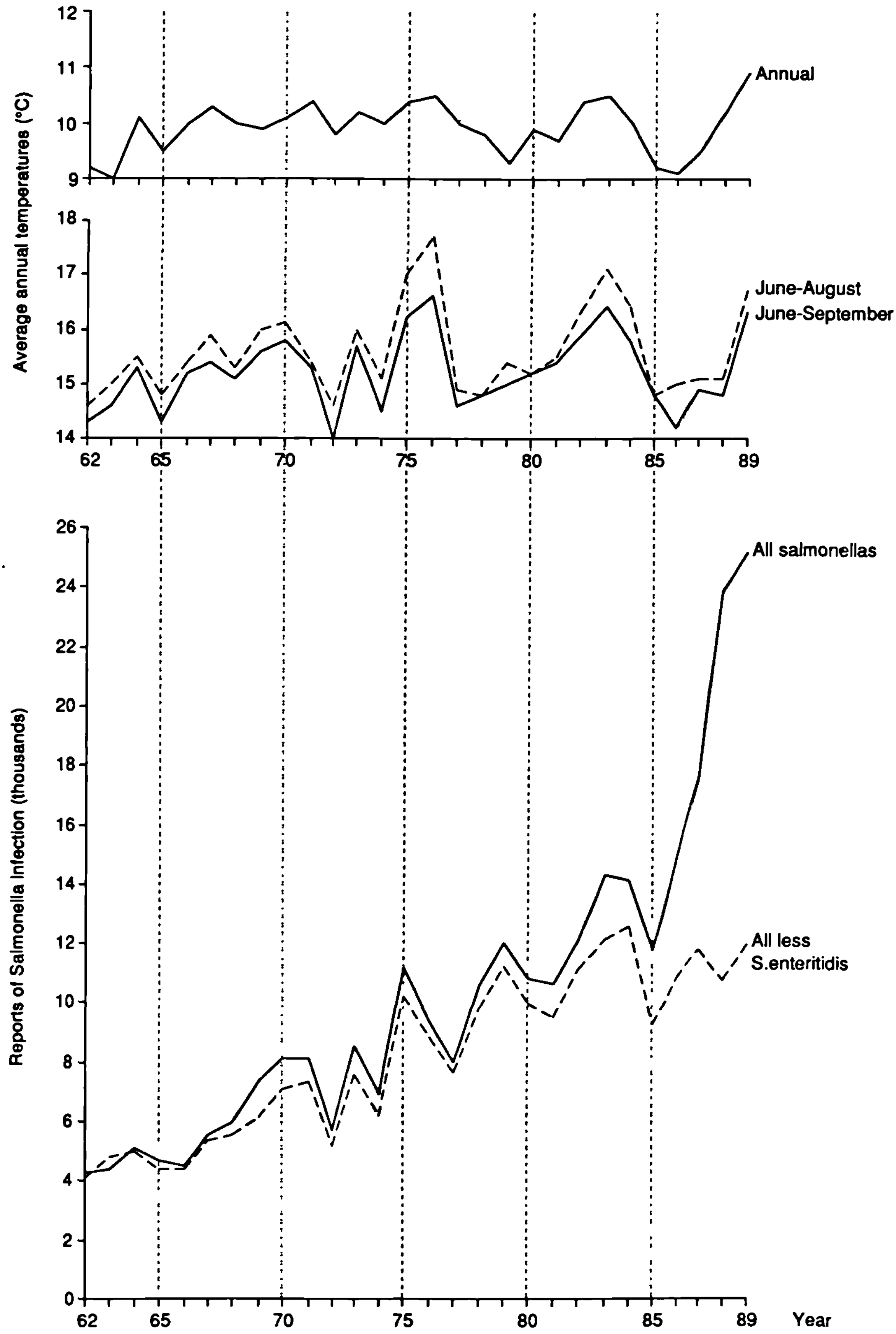


Table 3.9

Relationship between annual human salmonellosis and annual average temperature. Results of GLIM regression analysis

Organism	Degrees of freedom	Number of years	Temperature (in °C)									
			June		July		August		September		JJAS*	
			Est[1]	SE[2]	Est[1]	SE[2]	Est[1]	SE[2]	Est[1]	SE[2]	Est[1]	SE[2]
All salmonellas	20	23	370.1	215.5	453.6	209.8	692.6	256.1	481.8	304.4	1,088.0	314.6
All salmonellas excluding S. enteritidis	26	29	442.1	216.2	484.1	205.2	461.2	219.8	472.9	262.0	1,009.0	298.0
All salmonellas excluding S. typhimurium	20	23	172.0	200.6	129.0	204.2	333.6	254.1	341.6	275.3	484.2	334.8
All salmonellas excluding S. typhimurium & S. enteritidis	24	29	219.6	154.1	143.4	155.7	347.9	160.6	267.7	185.7	527.9	230.9
S. enteritidis	20	23	36.4	56.8	69.9	55.8	173.9	63.4	78.8	78.3	186.9	89.6
S. typhimurium	25	29	198.4	154.0	305.7	143.6	133.6	163.7	131.3	190.0	446.5	232.7

* June, July, August and September combined

[1] estimate; [2] standard error

Co-efficients represent average change in numbers of salmonellas per °C.

Basic regression model: total reports = $\alpha + \beta$. year + γ. temperature

The parameters α, β, γ represent, respectively, the intercept, the trend over time and the temperature dependence. Where appropriate year squared and/or year cubed were also entered into the regression equation to allow for non-linear trends over time. The estimates (Est) and standard errors (SE) of the parameter are presented in the table.

DISCUSSION

Introduction

Trends in food poisoning in England and Wales in the last 30 years appear to have been influenced by the incidence of salmonella infection as indicated by the similarity in the trends in statutory notification of food poisoning and laboratory reported salmonellosis. The trend in reported salmonella infection was steadily upward from the early 1960s and showed a marked increase after 1985 (Figures 3.1a,b). Other bacterial food poisoning accounted for a relatively small number of cases and have either remained steady or have declined since the late 1970s. A number of other infectious agents have recently been recognised as foodborne; with the exception of campylobacter the numbers of recorded infections was low (Galbraith et al, 1987b).

The current increase in salmonella infection in particular, has become a matter of public health and political importance for five reasons. Firstly, because of its size; the number of salmonella infections recorded in 1990 was almost five times that recorded in 1960. Secondly, the increase, which has been evident since the mid-1960s, has been virtually continuous. Thirdly, the rate of increase in annual salmonella reports to CDSC rose markedly after 1985 to unprecedented levels and was, on average, 17.4% annually in the period 1986 to 1989. Fourthly, the increase since 1986 has been associated with a single serotype, **S. enteritidis**. Fifthly, the increase in **S. enteritidis** infection has been largely ascribed to poultry and egg products and has resulted in Government action to control infection in these products and prompted major Government reviews of the causes and control of foodborne illness (Agriculture Committee First Report, 1989; Report of the Committee on the Microbiological Safety of Food, 1990).

The aim of this chapter was to explore the factors which may have contributed to the increase in salmonellosis since 1960 and to identify those factors which may be amenable to prevention. To do this three basic questions were posed. Is the increase real? How severe is the problem? What factors have influenced risk of human infection?

Is the increase real?

The evidence presented in this chapter is strongly suggestive of a real increase in human salmonellosis. However, potential biases relating to the way cases and outbreaks are ascertained and the quality of data means that the information has to be interpreted with caution. The absence of patient-based denominators means that the data can only reflect trends in reporting and some biases, discussed in Chapter I, could cause short-term variations in trends. For example dips in the main peaks in 1984, 86 and 88 coincided with postal strikes which delayed delivery of laboratory reports to CDSC. Longer-term effects, such as changes in the numbers of reporting laboratories, may result in evolutionary changes in systems. There is, however, evidence to suggest that the upward trend in numbers of cases of food poisoning in general, and salmonellosis in particular, is real and, to some extent, explainable. Five tests to support this view were applied to the data.

Consistency.

Both notifications of food poisoning and laboratory reported salmonellosis exhibited a consistent upward trend (Figure 3.1a,b). It was unlikely that this trend was influenced by evolution of the systems of data collection, although these processes can have a strong effect in the early years of reporting (Galbraith, 1990). Both the voluntary laboratory reporting scheme and the system for statutory notification of food poisoning were established up to 20 years prior to the period under review and remained essentially unchanged until 1989.

Any effect on ascertainment of laboratory confirmed salmonella infection resulting from increased numbers of participating laboratories was likely to be minimal. The number of PHLs, which contribute up to a half of reports to CDSC, had not changed since 1980 (Williams, 1985) and the number of other laboratories has declined. A more accurate appraisal would be based on the numbers of persons tested and the proportion of positive isolations made from them but these data are largely unavailable. However, limited information on the number of faecal specimens and rectal swabs tested by PHLs in 1965 (448,508) compared with estimates for 1989 (458,770) indicated a 2% increase in numbers tested compared with a 400% increase in the number of salmonella isolations (unpublished data).

Changes to the notification system such as increasing payment appear to have had little effect on notification rates (McCormick, 1987). The introduction of the category of "cases ascertained by other means" in 1982 did increase ascertainment of cases of food poisoning but did not appear to affect trends in formal notifications.

Trends in food poisoning notifications at Regional Health Authority level appear to be consistent with national trends, suggesting these trends are real (Figure 3.3). However, annual variations between notifications and laboratory reports within regions were more evident (Figure 3.3). The consistently high reporting in Yorkshire, for example, may suggest a local consensus on reporting practice as well as indicate local endemicity of salmonellosis. The former possibility was strengthened by analysis of reporting within Yorkshire Region (Appendix 3d). West and North Yorkshire showed similar recent rises in salmonellosis whereas Humberside did not. Within West Yorkshire, of the five districts examined, three showed significantly increased reporting rates in 1988 and two did not. Such results in adjacent districts would suggest local reporting practice could influence observed trends. The possibility that such differences also indicated variations in laboratory methods and willingness to take specimens for culture cannot be excluded. Nevertheless, providing that any constraints on reporting are applied reasonably consistently over time then they may not unduly affect overall national trends.

Comparability.

Although obtained by different mechanisms, when plotted together (Figures 3.1a,b) trends in food poisoning notifications and laboratory reported salmonella isolations were very similar. Although numbers were smaller and therefore more likely to be subject to local variation, comparisons made between notifications and laboratory reports of salmonellas at the level of Regional Health Authority also exhibited strong similarities (Figures 3.3). The divergence between food poisoning notifications and salmonella reports since 1985 does suggest other factors may have affected trends. The recognition of **Listeria monocytogenes**, Yersinia and verocytotoxin producing **Escherichia coli** as being foodborne, would have had only a minimal effect because the numbers involved were small (less than 500 per year of laboratory reports) and the clinical presentation in many cases would not suggest food poisoning. However, campylobacter enteritis which has been more commonly reported than salmonellosis since 1983, is also recognised as being possibly foodborne and an increasing number may be included in notifications.

Increased media interest and publicity about food poisoning* may have resulted in increased consultation with doctors and a greater likelihood that such cases are notified and specimens submitted for laboratory examination. However, media interest was not heightened until late in 1988, following comments by a junior Government Minister, two years after the increased upward trend had been observed.

Selectivity.
Evidence of the validity of the increase in salmonellosis related to the reporting of specific serotypes. It is impossible for a doctor to be selective of particular serotypes at the point at which a specimen is taken for testing. Therefore the occurrence of particular serotypes is likely to be an indication of their prevalence in the community.

Only 35 serotypes recorded between 1962 and 1989 occurred in the annual ten most frequently reported types (Appendix 3g), and only 3 serotypes **S. typhimurium**, **S. enteritidis** and **S. virchow** were consistently in the first three. For serotypes of a lower ranking, the occurrence of a single outbreak may have affected reporting. It appears that some serotypes, including **S. typhimurium**, **S. enteritidis** and **S. virchow**, reported over many years have an established endemicity. For others, including **S. agona** and **S. hadar**, associated with poultry, this was more transient although reporting continued at a low level. Whereas yet other serotypes, such as **S. napoli**, associated with chocolate, peaked then disappeared. This pattern suggested that for a serotype to become "endemic" in the human population the serotype first needs to establish itself in an animal which provides a major contribution to human diet.

A series of serotypes which peaked in the 1960s and 1970s were largely responsible for maintaining the upward trend over that period, however the current increase was due entirely to reports of **S. enteritidis**,

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* The number of articles relating to food poisoning published by the major national newspapers rose from 57 in 1985 to 254 in 1988 (A. Halligan, Leatherhead Food RA, personal communication).

particularly **PT 4** (McCoy, 1975; Agriculture Committee First Report, 1989; Galbraith, 1990). This increase became apparent in 1986 and preceded media, public and Government interest (Figure 3.6). The current peak in **S. enteritidis** is different in its magnitude from previous peaks due to other serotypes, with over 13,000 reports to CDSC in 1989 compared with just over 2,000 of **S. hadar** in 1979.

The national increase in **S. enteritidis** was reflected by similar trends in each of the NHS Regions (Figure 3.4). However, there was variation between regions as to the point at which the increase started. A consistent increase in reporting started as early as 1978 in SW Thames and in 1982 and 1983 in Northern, Yorkshire, Oxford and S Western; the remaining regions increased about 1986. In all regions the recent rise coincided with increased reporting of **PT4**. Reporting rates by region for **S. typhimurium** and **S. virchow**, showed different trends. Peak rates were generally lower for **S. typhimurium** and considerably lower for **S. virchow**. Patterns in reporting rates were less consistent between regions for **S. typhimurium** and showed greater variability within regions. That this could be influenced by specific strains was indicated by reporting of three phage types of **S. typhimurium** in Yorkshire Region in 1983 (Appendix 3e).

Plausibility.

Many serotypes associated with the salmonella increase in the 1960s and 1970s were introduced in imported breeding stock and contaminated feed for the pig and poultry industries (Lee, 1974; McCoy, 1975). Spread in animals and poultry was facilitated by intensive rearing methods*.

Poultry became the cheapest of the popular meats to produce (Spedding, 1988) and introduction of fresh and frozen, oven-ready birds and growth in freezer ownership combined to make poultry increasingly popular (Figure 3.15,16) (MLC, 1991). Testing of both imported and domestic feedstuffs indicated considerable problems of salmonella contamination which, despite legislation to monitor and control contamination continues to occur (Report of a Working Party of the PHLS, 1961; Report of the Joint Working Party of the Veterinary Laboratory Service of the

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*The modern broiler industry was established in the early 1960s following de-rationing of animal feedstuffs, resumption of importation of animal feeds and the growth of intensive rearing.

MAFF and the PHLS, 1965; Dawkins and Robertson, 1967).

That poultry acted as a vehicle of human salmonellosis was indicated by the occurrence of human infections due to serotypes introduced into poultry (Lee, 1974). For example, **S. virchow** introduced into chicken flocks in north-west England in the mid-1960s (Vernon, 1969); **S. hadar** introduction into poultry, particularly turkeys, via feed in the late 1960s; **S. enteritidis** introduction into flocks probably via imported chicks and eggs in the late 1960s (Lee, 1974; McCoy, 1975); **S. agona** introduced into poultry via Peruvian fish meal in 1970. Periodic surveys of poultry carcases (fresh and frozen) found consistently high levels of contamination (D. Roberts, PHLS Food Hygiene Laboratory, personal communication) indicating they may act as direct vehicles of infection or indirectly via contamination of surfaces with which they come in contact. Similar introduction of specific serotypes into pigs occurred over the same period (Newell et al, 1959; Lee et al, 1972).

A major difference between the current increase and the more steady rise in salmonella infection since the 1960s was its size and its association with just a single serotype which had been commonly reported for many years. **S. enteritidis** had caused a comparatively small peak in the late 1960s and appeared to be mainly associated with poultry. Reporting levels were further maintained by infections in visitors to Spain, the Balearic Islands and Portugal; in some years imported infections may have accounted for up to half those recorded (L Ward, DEP, personal communication). The recent increase has been ascribed to poultry meat and internally contaminated egg. Poultry contamination by **S. enteritidis** was well known and the Government's Agriculture Committee First Report (1989) described the internally contaminated egg as "a new dimension". Reasons for associating the recent increase in **S. enteritidis** with hens eggs are summarised below:

1) Increased human infection with **S. enteritidis** began in different parts of the country at different times starting in 1978 (Figure 3.4). This would correspond with the spread of contamination of broiler and laying flocks over a period of time (Humphrey et al, 1988).

2) A marked increase in outbreaks implicating eggs was recorded from 1988 (Figure 3.13). This corresponded with increased reporting of

incidents in poultry from 1986 (Figure 3.14), before statutory testing of flocks was introduced in 1989.

3) Case-control studies in England and in Wales, and detailed investigations of outbreaks implicated eggs or egg-containing foods as vehicles of infection (Coyle et al, 1988; Agriculture Committee First Report, 1989; Cowden et al, 1989b,c; Hawker, 1992).

4) Systemic infection of poultry by **S. enteritidis** which could lead to infection of the ovaries and hence internal contamination of eggs was reported in 1988 (O' Brien, 1988; Gast and Beard, 1990).

5) **S. enteritidis PT 4** has been isolated from the contents of intact eggs from flocks implicated in outbreaks (Paul and Batchelor, 1988; Mawer et al, 1989).

6) Multiplication of salmonellas was demonstrated in intact eggs; **S. enteritidis** can survive light cooking (Humphrey et al, 1989a).

7) Poultry for both broiler and layer flocks are derived from a limited number of parent flocks and grandparent flocks. Infection of just a few of these flocks would lead to fairly rapid dissemination of the organism to producer flocks.

8) The slaughter of only a few contaminated chickens at a poultry processing plant would lead to the widespread contamination of carcases in that plant (Jones et al, 1991).

The mechanisms by which poultry and eggs can become contaminated, the widespread use of these products, and the epidemiological and microbiological evidence indicate the plausibility of these products as the sources of the epidemic of **S. enteritidis**. The assertion that contaminated eggs were a main cause of the current epidemic has been challenged on the basis that many reported investigations have failed to provide conclusive microbiological evidence that a contaminated egg was the source of human illness. A second contention was that poor kitchen hygiene was a more likely explanation for outbreaks than contaminated eggs (Duguid and North, 1991). This challenge, however, fails to take into account the epidemiological and microbiological evidence as well as similar findings in other countries.

International perspective.
Increases in salmonella infection have been observed in both Europe and North America (Figure 1.1) and the recording of outbreaks in England and Wales due to **S. enteritidis** contamination of imported European eggs indicates the problem is of international importance (Stevens et al, 1989; Perales and Audicana, 1989; Rodrigue et al, 1990; Telzak et al, 1990; Notermans and van de Giessen, 1992). This may not be surprising when seen in the context of the international movement of poultry breeding stock derived from a limited number of grandparent flocks in Europe and North America. Grade A shell eggs were associated with **S. enteritidis** outbreaks in the USA and were implicated as the source of infection in three quarters of outbreaks in which a food was implicated between 1985 and 1989 (Bean and Griffin, 1990; St Louis et al, 1988)*.

How severe is the problem?

This section considers both the size of the problem in terms of the numbers affected and the seriousness of the illness. There is little information about levels of under-ascertainment of food poisoning and salmonellosis in England and Wales. To estimate the incidence of food poisoning and gastroenteritis in England and Wales the MAFF included questions on experience of stomach upset in the six months prior to interview in a survey of general public knowledge of food hygiene in 1988 (MAFF, 1988)**.

Estimation of annual total salmonella cases in England and Wales.
Extrapolation of the findings of the MAFF survey to the population of England and Wales in 1988 (estimated at 51.171 million) would suggest

*Experimental work in the USA has also confirmed the potential for artificially, orally contaminated hens to become colonised and excrete **S. enteritidis** for prolonged periods. **S. enteritidis** was also recovered from internal organs including the ovaries and oviducts, and eggs from contaminated flocks (in small numbers) were shown to be internally contaminated, particularly the yolk membrane or albumen (Gast and Beard, 1990).

**The survey was based on a random sample of adults aged 16 years or over. Forty-three per cent of interviewees said they had experienced diarrhoea or vomiting including 4% who thought their illness was due to something they had eaten. Of these, 17% said they had reported their illness to either a doctor or their local EHD.

that there were approximately two million cases of foodborne illness in that year. Assuming the distribution of these cases by causal organism in the population was similar to that of laboratory reported cases, then 43% or 874,000 were due to salmonellosis, of which 17% or 149,000 reported their infection. Since about 23,000 cases were reported by laboratories to CDSC, then about 1/6.5 ascertained cases were reported and 1/38 of all cases were reported.

These estimates were based on the bold assumptions that the distribution of cases of gastroenteritis as reported by laboratories is similar to that which occurs in the community and that individuals interviewed in the MAFF survey correctly attributed their illness to a food source. No data currently exist to check these assumptions; however, the estimates are in the same range of under-reporting levels suggested by one of the more conservative studies reported from the USA (Chalker and Blaser, 1988). The Richmond Committee has recommended that studies should be carried out in England and Wales to evaluate the incidence of gastrointestinal infection in the community, the agents responsible for infection and the economic burden of these infections on the economy (Report of the Committee on the Microbiological Safety of Food, 1990).

Severity of illness.

On the basis of the information available from laboratory reports and death registrations the severity of reported salmonella infection fell into three broad categories: death, bacteraemia and meningitis or other serious complications, and uncomplicated gastroenteritis.

Death: death from salmonella infection is comparatively rare and information presented in this study indicated an annual average of four deaths per 1,000 notifications of food poisoning or laboratory confirmed salmonella infection for the period 1960 to 1985, but then declined to about two deaths per 1,000. The decline in the death rate may have resulted from, first, the possibility that doctors changed practice with regard to recording cause of death, although there is no evidence to support this. Second, increased ascertainment of cases had a diluting effect. Third, the death rate was diluted by the increasing dominance of **S. enteritidis** infection, which appears to be less likely to cause serious illness when compared with some other common serotypes

(Appendix 3f); probably a combination of these last two factors.

The possibility that isolation of salmonella in a patient was incidental to death was considered. Laboratory data suggested that salmonella infection was the cause of death in about 71% of reported salmonella associated deaths. Most patients had a diarrhoeal illness and in many cases this was coincidental with, or a precursor to, a more serious systemic infection (Dr S Young, CDSC; personal communication).

Bacteraemia, meningitis or other serious complications: serious illness was recorded in 14 of every 1000 reported cases, approximately a fifth of whom died. Bacteraemia and meningitis, as indicated by positive blood or CSF culture, were the most common presentations. The risk of developing these conditions was greatest in infants, young children and older adults for bacteraemia and in infants for meningitis (Table 3.3). There was a greater chance of developing bacteraemia in male infants and men aged over 45 years, particularly men aged 65 years and over, than in females in the same age groups. Other complications, particularly genito-urinary, biliary tract and bone/joint infections, were recorded in 434 cases, the majority of whom were adults. The risk of serious complications varied with the serotype causing infection. Thus, although on average about 1.4% of reported infections were of bacteraemia, the possibility of having a bacteraemia increased with some serotypes and was particularly high for **S. dublin** and **S. cholerae-suis** (Appendix 3f).

There may be under-linking of salmonella infection with some sequelae. Maki-Ikola and Granfors (1992) presented evidence that reactive arthritis occurred in upto 7.3% of cases and that this condition may be particularly linked to infection with **S. enteritidis** and **S. typhimurium** and serotypes with O antigens in common with these serotypes.

An additional factor relating to the treatment of serious illness is the occurrence of multiple antibiotic resistant strains of salmonellas. In the UK such strains are unusual although the proportion of multiply resistant strains of **S. typhimurium** and **S. virchow** increased significantly between 1981 and 1988 (Ward et al, 1990) and at least one multiply resistant strain of **S. typhimurium** previously common in cattle has been found in poultry (Threllfall et al, 1990).

The data indicated that serious illness due to salmonella infection is relatively uncommon in the UK, and other complications even rarer although the level of underascertainment is unknown. The importance of these illnesses lies in the protracted course of the illness and the attendant costs. For example, bone/joint salmonella infections may take a protracted course, treatment may not be entirely successful and the treatment may cause further complications (Diggs, 1967; Adeyokunnu and Hendrickse, 1980; Molyneux and French, 1982; Anon, 1983).

Uncomplicated gastroenteritis: the majority of cases reported had a relatively uncomplicated gastroenteritis, however this may incorporate a very wide range of severity of illness which relates to the number and type of symptoms, the relative severity of each symptom and the length of illness. These aspects are explored in detail in Chapter 4. In addition are those individuals whose illness was mild and who mostly recovered without medical attention and therefore went unrecorded. Estimates for these would suggest there are between 9,000 and 37,000 additional cases for every 1,000 reported. The illness related costs per case for these infections is likely to be low but may be substantial when taken as a whole.

What factors have influenced risks of human salmonella infection?

Most laboratory reported salmonella infections were of apparently sporadic cases (Figure 3.9). There is little information about the risk factors associated with most of these infections and it may be that many are part of unrecognised outbreaks. Thus if a common food was distributed widely both geographically and in time, then the resulting cases would show a similarly wide distribution and a common vehicle would be difficult to identify (Galbraith, 1990). Such an outbreak would be made even more difficult to identify if the cases were due to a common salmonella. When widespread illness is attributed to an unusual serotype the cases are more easily recognised as an outbreak and therefore investigated, thereby increasing the likelihood that a food vehicle will be identified (Gill et al, 1983; Rowe et al, 1987; O'Mahony et al, 1990a; Cowden et al, 1989a; Joseph et al, 1991).

That many sporadic cases were associated with unrecognised outbreaks was indicated for three reasons. First, the serotypes associated with most sporadic cases are the same as those associated with known reported outbreaks, associated food vehicles and infections in food animals. Thus the current increase in sporadic human cases corresponds with an increase in **S. enteritidis** infection and increases in outbreaks attributed to poultry and egg containing foods contaminated with **S. enteritidis** (Table 3.7) and in **S. enteritidis** infection in poultry (Figure 3.14). A similar phenomenon was observed with increased **S. typhimurium** infection in humans and cattle in the early 1980s (Sockett et al, 1986) and previously in the 1950s and early 1960s (MAFF and PHLS Joint Working Party, 1965; Anderson et al, 1961; Report of a Working Party of the PHLS, 1964). Tracing **S. typhimurium** infections in humans, foods and animals was facilitated by phage typing schemes which now extend to other serotypes (Callow, 1959; Anderson, 1960; Anderson, 1969; Duguid et al, 1975; Anderson et al, 1978; Barker and Old, 1979; Holmberg et al, 1984; Ward et al, 1987; Threlfall et al, 1989).

Second, changes in the laboratory reporting system in 1989 enabled cases with common family names to be identified as family outbreaks. This resulted in a two- to three-fold increase in the number of family outbreaks ascertained (Figure 3.8). This finding was not unexpected; a study of salmonella infection in 580 households in Enfield from 1953-1968 showed that other family members were infected in 36% of households where a case had been identified (Thomas and Mogford, 1970).

Third, case-control studies of sporadic cases of **S. enteritidis PT 4** infection in Wales (Coyle et al, 1988) and England (Cowden et al, 1989a) showed an association between illness and eating chicken and foods containing fresh shell egg. There was evidence implicating these foods as vehicles in outbreaks and of **S. enteritidis** contamination of poultry and eggs (Paul and Batchelor, 1988; Cowden et al, 1989b; Mawer et al, 1989).

It seems reasonable to assume that most salmonella infection is food-borne and the factors which may influence foodborne spread of infection are considered below. These included intrinsic factors related to the type of food and its preparation and extrinsic factors such as infections in food animals, patterns of food consumption and ambient temperature which may act to introduce or amplify contamination.

Food.

Outbreak reports by laboratories and local authorities were the only consistent source of information on foods implicated as vehicles of salmonella infection over the period reviewed. The data were analysed to identify foods with a high associated risk of salmonellosis while the potential biases inherent in the data were borne in mind.

Microbiological or epidemiological evidence of the association of illness with a particular food was given in only a fifth of salmonella outbreaks (Table 3.6) compared with higher proportions in outbreaks due to other bacteria. Evidence appeared to be more likely to be obtained when the incubation period was short. For example, in Staphylococcal and Bacillus food poisoning the incubation period is usually one to six hours and food remnants are more likely to be available for testing. Salmonellosis has a longer incubation (usually 1 - 3 days) and by the time infection was apparent, food remnants may have been discarded and cases may have difficulty in remembering what they had eaten.

To explore the relevance of the different categories of food as vehicles of infection, reporting trends over time were analysed. If these trends were entirely anomalous then the observed patterns in reporting would be less likely to be independently supported by additional factors such as the type of salmonella identified, the type of population affected or trends in food consumption patterns. Although a wide range of foods were implicated in outbreaks the majority fell into the categories of meat and primary agricultural products. Most of these products were derived directly from animals, i.e. dairy products and eggs, and some outbreaks were attributed to raw foods of vegetable origin, including spices, beansprouts, sugar-cane and coconut (Galbraith et al ,1960; Anon, 1978a; Gustavsen and Breen, 1984; Anon, 1988; O'Mahoney et al, 1990a). In these instances the product may have been contaminated by animals during growth or processing.

Three types of meat or meat product were of particular importance: poultry, pork/ham and processed meats and pies. Poultry was the most commonly implicated meat and the majority of these outbreaks were due to salmonellas. The steady increase in poultry-associated outbreaks corresponded with the increasing popularity of poultry meat (Figures 3.15,16). Pork and ham were also often associated with salmonella infection. In contrast, salmonella outbreaks associated with beef or sheep meat were less common. In addition, salmonellas were the single most common cause of illness associated with eating processed meats, meat pies and pasties, etc. This may reflect the degree of handling in the preparation of such foods and the conditions of storage of foods which may not be further cooked prior to eating.

The continued association of salmonellosis with meats and meat products is an indication of the difficulties of controlling contamination of products from animal sources. A series of studies and reports in the UK in the 1950s and 1960s confirmed the chain of infection from animals to man (Anderson et al, 1961; Galbraith, 1961; Hobbs, 1961; Lee, 1974). Specific problem areas identified were feed contamination (Report of a Working Party of the PHLS, 1961; Dawkins and Robertson, 1967; Harvey and Price, 1967a; Patterson, 1972), control of cross-infection and cross-contamination at the farm, during transport of animals and at the abattoir (Ritchi and Clayton, 1951; Harvey and Powell-Phillips, 1961; Report of a Working Party of the PHLS, 1964; Dixon and Peacock, 1965; Hugh-Jones, 1969; Payne, 1969; Bicknell, 1972; Lee et al, 1972; Ghosh, 1972; PHLS Working Group, 1972; Clegg et al, 1986; Morgan et al, 1987; Wray et al, 1987; Wray et al, 1990), and prevention of contamination of finished raw products (Galbraith et al, 1964; Roberts et al, 1975; Lillard, 1989).

Of the "other foods" considered, the most important categories were milk and dairy products and eggs and egg-containing foods. Outbreaks due to milk were particularly associated with drinking unpasteurised milk and the majority were caused by **S. typhimurium** infection. An increase in the period 1980 to 1985 coincided with an increase in reporting of human **S. typhimurium** infections and the predominance of **S. typhimurium** as the major cause of infection in cattle (Figure 3.14). Salmonella infection associated with eating eggs and egg-containing foods has recently re-emerged and has been particularly associated with **S. enteritidis**. High levels of poultry contamination, reports of systemic infection in chickens and isolation of the organism from the contents of intact eggs were also reported over the same period (O'Brien, 1988; Humphrey et al, 1989a,b,c, 1991). Earlier problems were associated with duck eggs and imported hen egg products including dried and frozen egg (Report of the PHLS, 1958; Taylor et al, 1965).

Whilst contaminated poultry is likely to have been a significant vehicle for the increase in **S. enteritidis** infection, evidence suggested that internally infected egg added a new dimension to the problem. Although the proportion of contaminated eggs appeared to be low and to fluctuate (Humphrey, 1989b), about 30 million are produced daily and many eggs may be combined in an egg-containing dish, thereby increasing the chances of an infected egg being included. The number of outbreaks due to poultry declined over the period when egg outbreaks increased (Figure 3.11,13). This was despite public concern over food poisoning and presumably a greater likelihood of outbreaks being reported. Lastly, the predominance of one particular strain and the plausibility of egg as a source of infection provided strong evidence of the importance of contaminated eggs in the current epidemic.

Relatively few outbreaks were associated with manufactured foods in comparison with the total number recorded. However, their implications can be far reaching for the consumer, the manufacturer and for public health agencies. Salmonellas accounted for 45% of outbreaks reviewed in Appendix 3i. Manufactured products are distributed widely and produced in large quantity and have the potential to affect many people geographically widespread (Gill et al, 1983; Rowe et al, 1987; Cowden et al, 1989a). The food may be recalled and the manufacturer may bear considerable economic loss (Sockett, 1991b,c). They also highlight the value of safe standards, the importance of careful assessment of production processes through such techniques as HACCP, responsible attitudes, good standards of hygiene and innovation in the way processes are monitored and risks and standards assessed (Bryan, 1990; Skovgaard, 1990). With the increasingly international nature of the food trade, particularly within the EC where the formation of the single market in 1992 will lead to free movement between member states, the potential for international outbreaks is increasing.

Preparation.

The proportion of outbreaks due to salmonella infection varied with the place where the food was prepared and may have reflected the type and scale of catering involved. Thus salmonellosis was particularly associated with domestic situations (family outbreaks), restaurants and receptions and hospitals (Figures 3.8,10). Single households have consistently accounted for the majority of salmonella outbreaks recorded (Figure 3.8). Poor handling practices in the domestic kitchen, particularly in the preparation of poultry which has a high risk of contamination, may therefore have been an important contributory factor. Although there was no information about this in the outbreak reports received, consumer surveys commissioned by MAFF (1988) and J Sainsbury PLC (Anon, 1991a) showed that many people either did not know, or did not employ, basic rules of food hygiene.

Food preparation practices associated with general outbreaks fell into five categories. First, the restaurant type where most dishes would be prepared to order, although some constituents such as mayonnaise may be prepared in bulk beforehand and stored until needed. Second, the reception type, where menus may be limited and items prepared well before needed and stored ready to serve quickly. Third, the canteen type where salmonella infection was secondary to **Clostridium perfringens** intoxication, indicating that reheating of bulk prepared food is a more important consideration in these situations. Fourth, salmonella infection was the most common agent in outbreaks associated with shops; these commonly implicated sliced cooked meats or pies (Sockett, 1991b), and it is likely that cross-contamination via slicers, surfaces and hands were important contributory factors. Fifth, almost all outbreaks of the farm/dairy type were due to salmonella infection, and most outbreaks in which an associated food was mentioned were linked with either unpasteurised or inadequately pasteurised milk (Barrett, 1989; Sockett, 1991c).

Infection in animals

Trends in salmonella infections in animals showed similarities in their overall patterns to trends in food vehicles associated with human infection. The animal species most commonly reported were cattle and poultry. This corresponded with the recording of poultry, egg, beef and milk products as the foods most often associated with outbreaks. Peaks in salmonella infection in poultry in the early 1980s and from 1988 coincided with peaks in outbreaks of human infection associated with poultry (1980) and egg-containing foods (from 1988). Introduction of Statutory Testing of poultry including egg-laying flocks in 1989*

*The Poultry Breeding Flocks and Hatcheries (Registration and Testing) Order, 1989.

affected trends thereafter. Similarly, peaks in outbreaks due to beef and milk in the early to mid 1980s corresponded with an increase in recorded incidents in cattle (Table 3.5; Figures 3.12,13,14).

Trends in incidents in animals were influenced by a small number of serotypes, most also common in humans. Host adapted serotypes commonly caused infection in animals and may be a source of serious economic loss, but they do not cause human infection and obviously diseased animals are unlikely to be used for human consumption. Human illness therefore appeared to be associated with gastrointestinal carriage of salmonellas by the animal. Poultry, for example, have been shown to carry salmonellas without symptoms (Brownell et al, 1970; Fanelli et al, 1971). However, stress resulting from crowding and transportation of animals and poultry may increase levels of excretion and spread of infection, and spillage of gut contents during slaughter can act as a major source of cross-contamination of carcase meat (Notermans et al, 1975; Wray et al, 1987, 1990; Jones et al, 1991).

Human **S. typhimurium** infections increased during the early 1980s at the same time as incidents in animals, particularly cattle. The phage types identified in cattle were markedly similar to the types causing human cases (Appendix 3h). Similarly, **S. enteritidis** increased in both humans and poultry from 1985. There was a greater variation in serotypes associated with poultry-borne infection when compared with cattle, sheep and pigs. This may indicate that poultry are exposed, probably via feeds, to a wider variety of serotypes and that their more intensive rearing may facilitate the spread of infection*.

The possibility of cross-infection spread within or between species other than poultry was indicated by the distribution of **S. typhimurium** phage types. There was a marked commonality between the commonest strains in cattle, sheep and pigs. However, only three phage types in the "top ten" for poultry were listed in the top ten for cattle. Cross-infection may occur during transport to, or at market, either by direct contact with other animals or indirectly from contaminated stalls. The conditions relevant to the transport and housing of animals at market

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*Apart from rabbit, chicken provides the highest yield of protein per hectare of the main sources of meat protein, reaching saleable weight in eight weeks (Spedding, 1988 .

appear to be an important factor in the spread of salmonella infection in cattle, particularly in calves (Galbraith, 1961; Wray et al, 1990). Poultry, on the other hand, have little, if any, contact with other species and do not usually go to market.

Infection of animals and poultry via contaminated feed is well recognised (PHLS Working Group, 1972; Lee et al, 1972); microbiological monitoring of feed has been carried out since 1981*. Data for 1989 indicated that a high proportion of batches tested were positive, and that imported feeds and feeds containing meat or offal and blood showed greater levels of contamination and a greater variety of salmonella species continuing a trend reported since 1982 (MAFF, 1989). Lee (1974) suggested there was strong circumstantial evidence that some serotypes, which first appeared in the 1960s and 1970s, were introduced via imported feeds and may have been maintained by recycling in feeds made from animal protein. Differences in the use of animal, rather than vegetable protein in feeds may also influence trends. Intensively reared animals and poultry are likely to be fed a high proportion of protein feeds of animal origin which are often contaminated. On the other hand, cattle and sheep are grazed and, to a lesser extent fed on feeds containing protein of vegetable origin, thus reducing both the chances of becoming infected or spreading infection (Spedding, 1988).

One further mechanism for the introduction of serotypes into animals was by imported infected breeding stock. For example, McCoy (1975) suggested that a number of serotypes were introduced into poultry in the UK in imported day-old chicks. Once established, the prevalence of such strains would be maintained by mechanisms described above.

Patterns of food consumption.
Changes were observed in patterns of meat consumption over the period reviewed. These related to the type of meat eaten and the way it was presented to the consumer. Some of these changes may have influenced trends in human salmonellosis and factors, including price and public confidence in the product, may have influenced meat eating.

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*Diseases of Animals (Protein Processing) Order, 1981 and the Processed Animal Protein Order, 1989

Patterns of expenditure on meat probably reflected those of meat consumption, and proportionately, expenditure on poultry and frozen and convenience foods rose whilst expenditure on other categories declined or was static since the mid 1970s (MLC, 1991, personal communication). Therefore, whilst overall meat supply appears relatively stable, demand for specific types of meat or meat product has varied. Demand for specific types of meat or meat products may be affected by external factors. Thus poultry prices in 1989 were low due to poor demand which may have resulted, at least in part, from consumer concern about salmonellosis (MLC, 1991). Similarly declining demand for beef may have followed public concern over BSE in cattle after 1987 (Collee, 1990).

Overall meat supply was maintained by a continuous increase in poultry production which was set against a decline in other meats (Figure 3.15). The switch to poultry may have financial benefits for both the consumer and the producer. The consumer has access to a cheap source of meat which in turn has probably acted to increase demand. In addition, consumption of chicken is far less seasonal than other meats and is high throughout the summer period when other meat is lowest (Figure 3.18). This may in turn reflect the short production cycle (weeks) compared with other meat animals (months) and the greater ease in intensive farming to stagger production so as to provide a constant supply. Of course it may simply reflect consumer preference.

Another change has been the movement away from fresh meat for immediate consumption (except poultry) towards frozen or processed meat products (Figure 3.17). Consumption of frozen foods and ready meals grew continuously in the 1980s and this corresponded with increased ownership of freezers which rose from 52% of households in 1980 to 84% in 1989, and a trend towards shopping at supermarkets (Table 3.8) (MLC, 1991). Shoppers spend less time shopping and apparently shop less frequently.

Information from Audits of Great Britain indicated that there is an increasing tendency for customers to purchase "fresh" meat for freezing rather than meat already frozen (MLC, 1991). The MLC suggests that "fresh" meat is perceived as being of better quality and that fresh meat purchases for home freezing will increase. This trend may be more significant in terms of food poisoning trends because it may increase handling of potentially contaminated products in the kitchen which may act as a source of cross-contamination to other foods.

The importance of poultry as a major vehicle of human salmonellosis relates to four factors. Increased consumption over the period reviewed, the high proportion of contaminated oven-ready birds, increased use of fresh chicken which may act as a source of contamination in the kitchen and high consumption, compared with other meats, in the summer months when high ambient temperature exaggerates risks associated with inappropriate handling, cooking and storage.

In addition, storage of food for several weeks in freezers and widespread distribution of products makes it difficult to identify specific products as vehicles in outbreaks and may partly explain the apparent increase in sporadic cases. The tendency to shop less frequently, from a single store, buying greater amounts to be stored and eaten over a period of weeks may exaggerate the effects of keeping fresh or frozen foods too warm during transportation home and inappropriate storage in the domestic situation.

Weather.

The within-year trends in salmonella infection indicate a close relationship between ambient temperature and increased recording of infections (Figure 3.2). Each year the numbers of cases recorded increases with the onset of warmer temperatures in May and June and do not decline until the autumn. This may coincide with changes in eating habits, including greater consumption of cold meats and barbecued meats. Ambient temperature may therefore be a confounding factor, prompting seasonal changes to eating practices which in themselves may be more risky, either because of undercooking, in the case of barbecues, or prolonged storage at high ambient temperatures.

Observation of long-term trends in salmonella indicated that annual trends were influenced by summer temperatures and that a hot summer resulted in a peak in reporting of salmonellosis (Figure 3.19). This was quantifiable, in that each 1°C rise in temperature resulted in a further 1,088 recorded human infections (Table 3.9) and may have implications for predictive modelling of trends in salmonellosis.

Multiplication of salmonellas in warm conditions may act to increase the pool of organisms available in the environment and thereby increase the chance that animals or their products will become infected or contaminated. Once a food is contaminated increased growth may result in a greater chance, first, that cross-contamination to other foods via surfaces will occur, and second, that enough organisms will survive preparation and consumption of food and reach the small intestine and cause infection. Essentially the margins for handling error decrease as temperatures increase towards the optimum for growth of salmonellae.

The underlying effect of temperature on reporting trends was weakened by the overwhelming increase in S. **enteritidis** after 1985. This suggested that an additional factor, eg. contaminated poultry and egg, which particularly influenced reporting of S. **enteritidis** after 1985, affected trends and appears to have acted independently of temperature. The possibility that temperature was significantly responsible for the rise in S. **enteritidis** is also less likely because the increase took place during a period of relatively low summer temperature.

Other sources of salmonellosis.

The most important "other" source of salmonella infections are those acquired abroad which account for over 12% of infections recorded annually, although the proportion may vary throughout the year*. Many of these infections were probably foodborne; however, they represent an important source of infections recorded in England and Wales. Although the reasons for the visits were not known, the destinations recorded and the seasonality of visits suggested the most likely reason was tourism (Figure 3.7). This is supported by data on estimated visits abroad based on the International Passenger Survey (DoE, 1990). Mediterranean countries were the most popular destinations, although the risk of acquiring infection varied with the country and were highest in North Africa and Asia (Table 3.4).

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*Human infection resulting from direct contact with animals does not appear to be important in the UK and few reports of such incidents have been received by CDSC (CDSC, unpublished data). Although, in at least one incident, cases of salmonellosis in a hospital were associated with wild birds entering the kitchen (Penfold et al, 1979). The exceptions to this may be contact with farm animals or exotic imported pets (Armentano et al, 1971; Anon, 1981a; Chiodini and Sundberg, 1981). Further investigation of these possibilities is warranted.

The data suggested that the risk of infection increased during the holiday season. To identify the reasons for this would require further investigations. However, possible explanations may include first, the difficulties in preparing and storing foods in very warm summer temperatures. Second, having to cope with very large numbers of tourists visiting a resort at any one time which may stretch local facilities to the limit. Visits to different parts of the world may have made different relative contributions to the overall seasonal pattern. Cases visiting European and Mediterranean countries contributed mainly to the Summer peak (Figure 3.7), whereas those who had been to the ISC and North Africa maintained the level of imported infections early in the year.

The results indicate that measures should be considered for preventing infection in visitors to countries where the risk was high, and reducing the possibility of transmitting imported infections, by food handlers and care workers. For example, educational material detailing the modes of spread of salmonella infection and its prevention should be particularly directed at visitors to "high" risk countries.

Factors affecting transmission of salmonella infection via food

The data presented indicate the factors affecting transmission of salmonella infection are either intrinsic or extrinsic to food production. Intrinsic factors relate to the type of food and it's preparation. Some foods carry a greater risk of contamination and some preparation practices may be more likely to result in cross contamination or proliferation of organisms in a food.

Extrinsic factors relate, firstly, to the contamination of raw materials, including animals (eg. via feeds). Such contamination or infection may be exacerbated by the way the material or animal is kept and transported. Secondly, environmental factors such as high ambient temperature may encourage proliferation of salmonellas. Thirdly, consumer demand may affect the supply of particular products, some of which may have a recognised high risk of contamination and some which may become more risky as a result of changes in production practices.

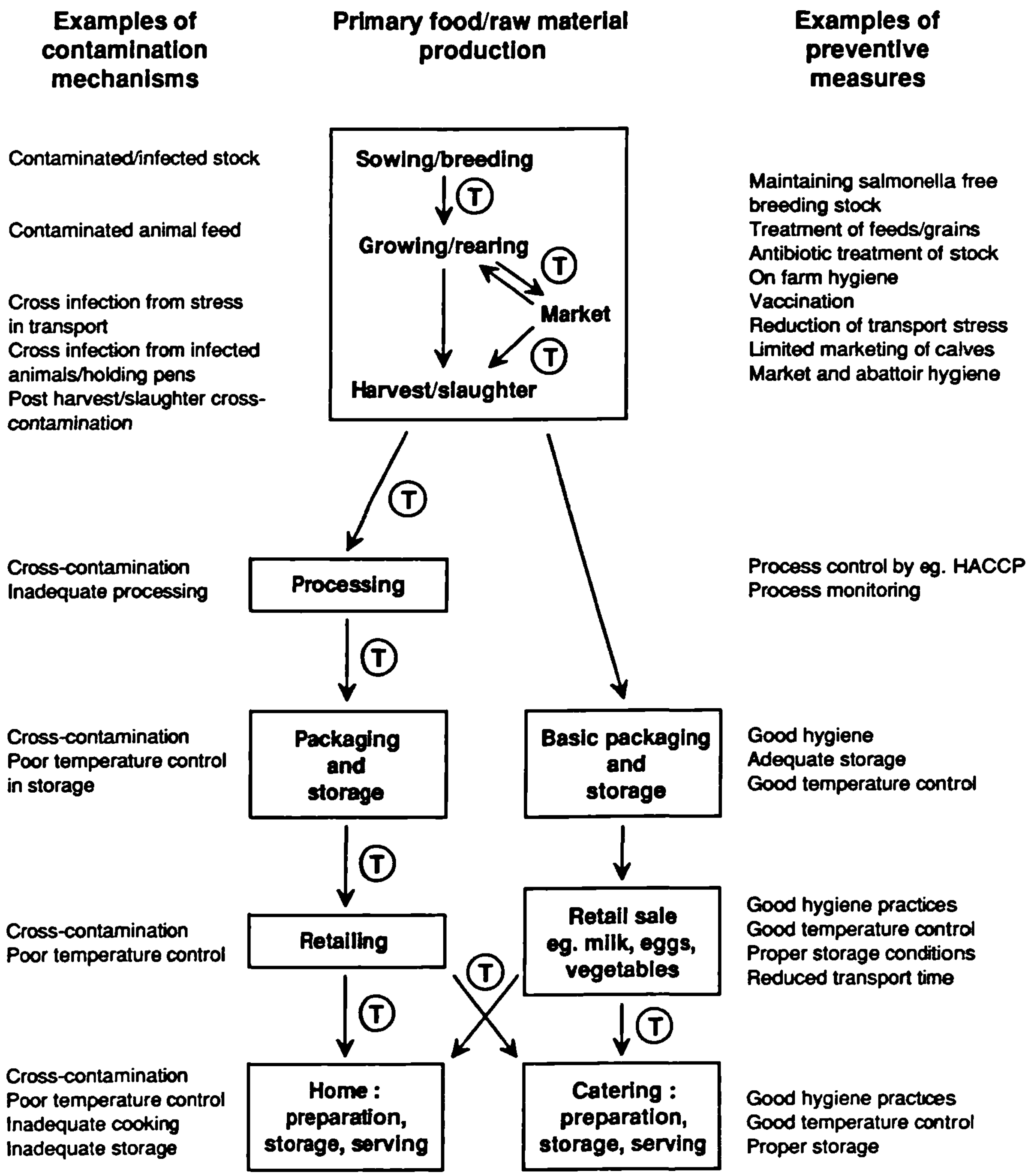
Some factors may be amenable to intervention or their riskiness may be reduced by modifying the effect they have. Thus identifying foods posing a particular risk of contamination, ensuring adequate processing of the food and encouraging high standards of hygiene during handling are likely to reduce the effect of intrinsic factors. Likewise, reducing contamination of raw materials, lowering storage temperatures and encouraging consumers to demand safer products, will reduce the effects of extrinsic factors.

Figure 3.20 shows the basic stages in food production and identifies mechanisms of contamination and preventive activities. In primary agricultural products infection or contamination may be introduced directly whereas from processing onwards problems relate either to cross-contamination or proliferation of organisms already present. Corresponding preventive activities thus relate to prevention or control of infection or contamination of the primary product and to the elimination of contamination, by heating, chemical treatment or irradiation, of the finished product or limitation of cross-contamination or bacterial growth during processing and retailing. Good hygiene practice become increasingly important post processing and, in essence, form the last line of defence. Obviously, any measures which reduce contamination at an earlier stage mean a failure during final preparation is less likely to result in illness from eating that particular food or to result in cross-contamination to other foods. Purchase of raw products is more likely to bring the consumer into contact with contaminated material. Thus external factors such as ambient temperature and good hygiene practices are of far greater importance in the handling of these foods.

Education of both commercial and domestic food handlers in good hygiene practices will continue to be of importance, although the effects of educational programmes is difficult to assess and may need to be continuous and innovative. Recent surveys of consumer understanding of the basic principles of safe food handling indicated little improvement in public knowledge between 1988 and 1991 (MAFF, 1988; Anon, 1991a). Timing of public education may also be of importance and the data presented on within year trends in salmonellosis (Figure 3.2) suggested education programmes should be timed for March to April, prior to the Summer peak, and in November, prior to the Christmas peak.

Figure 3.20

Food Production, Mechanisms of Contamination and Prevention of Contamination



(T) = Transportation (potential for cross contamination, poor temperature control and prolonged storage cond t ons)

The specific risk factors associated with salmonella infection identified by analysis of the outbreak data were of three types. First, the use of unsafe sources of food or foods which may be subject to contamination and not further processed before consumption. Although raw materials, particularly meat, are considered to be potentially contaminated in most circumstances, the actual risks associated with some of these materials may vary. The reasons for this related to the likelihood that the product was contaminated, whether it was to be processed and whether processing would be sufficient to kill salmonellas, the constituency of the food and even the health of the consumer. Thus, chicken meat would be high risk because the chances of contamination are high*. In most instances, however, cooking should drastically reduce the risk. In contrast, milk or egg may have a relatively lower risk of contamination, but because the product may be pooled, consumed raw or after only minimal heating the chances of infection may be increased if the food is contaminated by even low numbers of organisms. This effect may be enhanced by the composition of the food itself, thus low numbers of contaminating organisms have been associated with large outbreaks due to chocolate, cheese and powdered milk, all with a relatively high fat content (Greenwood and Hooper, 1983; D'Aoust, 1985; Fontaine et al, 1980; Rowe et al, 1987).

Second, the method of preparation or processing may be inadequate or made unsafe as a result in changes in procedure or by undetected damage to, or contamination of, equipment. Food may be inadequately thawed and cooked, or cooked food recontaminated. Such contamination could be enhanced by prolonged storage at or near ambient temperature.

Third, the food may be subject to poor handling at the retail and catering end of the chain. The potential for poor storage and handling to result in illness may be amplified at high ambient temperature. Thus the main peak in reported cases occurred in the Summer as did most outbreaks due to contaminated cooked meat products (Sockett, 1991b).

Assessment of risks associated with specific foods must take account of

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*Between 54% and 79% of carcasses examined in studies in England and Wales and elsewhere were contaminated with salmonellas (Agriculture Committee First Report, 1989; Gilbert and Roberts, 1986; Tokumaru et al, 1990; Jones et al, 1991).

diverse factors. Roberts (1991) reported that studies by the USA National Academy of Sciences have attempted to define such 'risk assessment' in statistical terms and provide a framework for evaluating risk. Roberts criticises the NAS procedure because of its reliance on laboratory tests which may show variability, take time and be costly.

For targeting preventive activities an approach based on assessment of a series of key factors may provide a more practical tool. This would allow the interrelationship between different factors, some of which may be difficult to quantify, to be considered. This would be improved and updated as further laboratory, epidemiological, sociological and economic data are made available.

Consumers may be swayed less by statistical evidence of the possibility of infection from a food than by factors such as price, fear, novelty, media interest, cultural beliefs and other actual or perceived health benefits or deficits. Poultry meat is often contaminated with salmonellas yet sales continue to rise; it is, however, cheap and perceived to be healthier than red meat. In contrast, egg sales dropped when an association between human illness and salmonellosis was publicised by the media. Consumer reaction was rapid despite government reassurance and the lower frequency of contamination when compared to poultry. This may have reflected both media hype causing fear and a challenge to prior consumer belief that eggs are safe.

Table 3.10 lists factors which could be of value in this type of approach, incorporating preparation and consumption factors as well as contamination potential. The public health significance (PHS) of a food was largely indicated by the annual average number of recorded outbreaks, but was evaluated in the context of other factors. This approach is dependent on what is reported and subjective interpretation of data. However, the results are consistent with the longer term trends presented in the results. Although Table 3.10 concentrates on salmonella outbreaks due to a range of foods this approach could be developed for specific serotypes, other organisms or foods.

The PHS of chicken was very high on the basis that it is commonly reported as associated with outbreaks. This is seen in the context that the serotypes commonly causing human illness are also found in isolates

Table 3.10

<u>Summary of criteria which could be used for modelling the Public Health Significance (PHS) of specific foods</u>

Food item	ESTIMATED LEVEL OF RISK				INFLUENCING FACTORS					
	Number of outbreaks*		Suggested PHS		Animal-related factors		Processing-related factors			
	Sal+	Obat‡	Sal+	Obat‡	Found in animal feed [1989]†	Found in live animals [1985-89] (%)	In raw/ uncooked product[a] (%)	Eaten raw/ unheated or lightly heated in processing	Eaten only after heating in processing or cooking	Risk of cross-contamination from raw product
Chicken	15.2	7.6	VH	H	✓	43.2	>50.0	-	✓	H
Turkey	9.0	4.2	H	M	✓	44.6	-	-	✓	H
Beef	3.2	8.6	M	H	✓	53.6	0.9	-	✓	L
Pork/ham	5.2	7.0	M	H	✓	39.0	2.2	-	✓	L
Lamb/mutton	<1.0	1.6	L	M	✓	34.2	1.0	-	✓	L
Processed meats/pies	12.4	16.2	VH	VH	NA	NA	NA	-	✓	L
Gravy, sauces	<1.0	<1.0	L	L	NA	NA	NA	-	✓	L
Milk/dairy products:										
Raw	4.8	<1.0	M	L	✓	-	-	✓	-	M
Pasteurised	<1.0	<1.0	L	L	✓	-	-	-	✓	L
Eggs (raw or lightly-cooked)	17.8	2.0	VH	M	✓	-	-	✓	-	M
Rice	<1.0	4.2	L	M	NA	NA	—	-	✓	M

* annual average over 5 years (1985–1989) + salmonella ‡ other bacterial agents

† one year only

PHS: average >10 = very high (VH); 5-10 = high (H); 1-5 = medium (M); <1 = low (L)

NA = not applicable;

Most data derived from tables in Chapter 3; [a] Turnbull and Rose (1982) from live chickens. Importantly, it is a high volume sales product, salmonellas are found on a high proportion of carcasses and there is a high degree of handling during preparation. These factors combine to give a high potential for cross contamination. Thus although it could be argued that chicken itself may not always be vehicle of infection, it may often be the means of entry of salmonellas into the kitchen.

Raw milk has a medium PHS on the basis of the number of outbreaks recorded. Consumption of raw milk has declined markedly in recent years (MMB, unpublished data) and the number of outbreaks recorded has decreased. If this trend continues the PHS of milk will decline further. Egg, particularly raw or lightly cooked egg, has a high PHS because of the large number of associated outbreaks and because although the numbers of potentially contaminated eggs is low and variable the volume consumed is high (30 million produced per day) (Anon, 1989). Thus the chance that cases will occur, particularly where a number of eggs may be pooled (eg. in mayonnaise), is increased (Humphrey et al, 1989b; Paul and Batchelor, 1988).

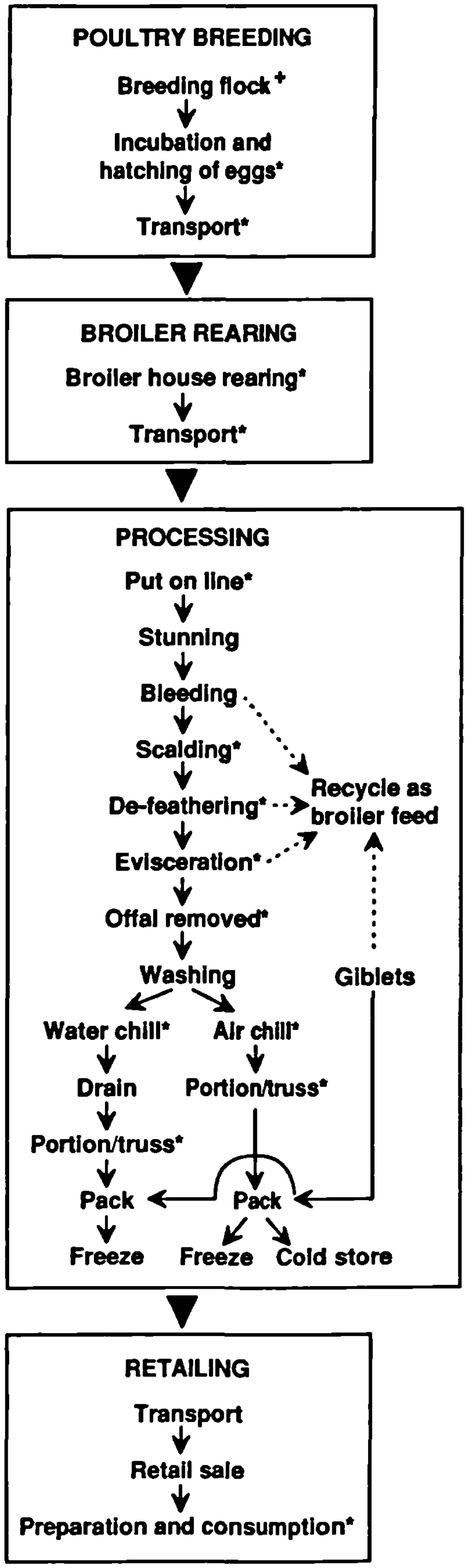
On the basis of the data presented in Table 3.10 three foods or products have a high PHS with other factors being important; chicken, processed meats and egg. This indicates that in terms of targeting a higher priority would be attached to these foods than to others listed.

The potential for salmonella contamination in poultry production

Figure 3.21 shows the main steps in the production of broiler chicken. This incorporates four stages: breeding, rearing, processing and retailing. Each stage comprises a number of steps and those which are at risk of contamination or cross-contamination are indicated together with possible interventions to prevent or limit spread. There are two main mechanisms for the introduction of salmonellas into the birds: contaminated feed and vertical transmission from breeder flocks (Williams, 1981). Humphrey et al (1988) commented that "existing measures do little to prevent potentially contaminated feed from entering the food chain." This is despite the introduction of statutory controls on the quality of animal protein feeds.

Until recently vertical transmission, via infected ovaries of parent

Poultry Production : Contamination Risk Points and Methods of Prevention



Possible interventions :

Egg fumigation and antibiotic treatment

Feed treatment (heat, chemical)
Antibiotic treatment
Competitive exclusion
Vaccination
Water chlorination
General hygiene
Shed fumigation
Stress reduction

Chemical, pH, heat treatments
Simultaneous scalding and plucking
Recycled products: heat and chemical treatment

Chlorinated wash water
Spray washing

Irradiation

Education in good hygiene practices

+ Vertical transmission
*** Main risk of cross-contamination**

birds, was thought to be rare and the most important mechanism was faecal contamination of the egg with passage of the organism through the shell as the egg cooled. However, direct ovarian transmission may have played a significant part in the recent spread of **S. enteritidis** infection. The organism has been shown to infect ovarian tissue but without marked adverse effects on fertility (Lister, 1988; Humphrey, 1989b). Thereafter cross infection results in spread to other birds or carcasses in crowded hatchery of rearing conditions (Cox et al, 1973). Other subsidiary factors such as spread by rodents, insects etc. cannot be ignored although the evidence for these is not convincing (Smith, 1971; Anon 1991b; Healing, 1991).

Until relatively recently it has been generally accepted that ingested salmonellae localise in the caeca of chickens but generally without causing clinical disease or commercial loss (Fanelli et al, 1971). However, **S. enteritidis** has been shown to cause systemic infection and to particularly locate in the oviduct and ovaries thus increasing the chances of vertical transmission occurring. This may now be of greater importance in relation to spread of **S. enteritidis** than other mechanisms (Lister, 1988; O'Brien, 1988).

Cross-infection and cross-contamination are probably the main mechanisms for spread of infection during both rearing and processing of poultry, and a number of steps in the production cycle are particularly susceptible. With the possible exception of irradiation, it is accepted that intervention procedures are at best only likely to reduce the load of salmonellas and other organisms on the carcass or reduce the chances of cross-contamination occurring.

Summary

It is likely that the trend of increasing food poisoning is real and that the main factors contributing to the increase relate both to the types of food eaten and the methods and conditions of preparation. The implication of foods of animal origin, including meat and other products not further processed such as raw milk and egg, being principle vehicles of infection was strengthened by reporting trends associating these foods with outbreaks of human illness, and trends in reporting of salmonella infection in animals and poultry. The current increase in **S. enteritidis** isolations, and the predominance of **PT4**, particularly associated with poultry products, suggests that a reduction in contamination of poultry could result in a significant decrease in human infection.

The problem of human salmonellosis is multi-factorial. Trends are driven by both intrinsic factors relating to the microbiological quality of the food we eat as well as the standards of preparation, and to extrinsic factors such as ambient temperature which act to amplify the intrinsic effects. Many of these factors may be amenable to preventive activities including programmes to reduce infection in animals and poultry and programmes to educate the consumer in safe food handling. Reductions in human illness could give substantial economic gains and the potential costs and benefits of alternative approaches are modelled in Chapter 5.

Chapter 4

ESTIMATION OF THE COSTS OF SALMONELLOSIS IN ENGLAND AND WALES
Results of a national survey of laboratory confirmed cases

The objectives of this study were to provide estimates of the costs of human salmonellosis to the public health services, the health sector and to affected individuals and their families, and to estimate the impact on the economy in terms of production loss. Finally, the information obtained would provide a framework for assessing the benefits which might accrue from preventive activities.

This chapter therefore describes a national survey of laboratory confirmed salmonella cases utilising a detailed questionnaire developed to explore the use and costs of environmental health and medical services, lost production to industry and costs to the infected individual and his or her family. A flow chart identifying the areas of cost to be assessed is presented in Appendix 4a.

This chapter is divided into methods, results and discussion. The methods section is divided into three parts which describe the survey, the structure of the questionnaire and the analysis of the survey data. Supplementary data sources used are described. The results section examines the characteristics and representativeness of the sample and presents the costs identified for the study sample. These were then extrapolated to provide an estimate of the annual costs associated with salmonellosis for England and Wales. The discussion is divided into two main sections. The first considers the results of the costing survey and the second discusses the extrapolation of the costs identified to the annual national impact of salmonella infection.

Included within these sections is discussion of the methods adopted and comparison, where appropriate, of the results of other studies. Modelling of alternative cost reducing activities, where these relate to cost reduction or preventive activities, is discussed in Chapter 5 although the methodology adopted is described in this methods section.

METHODS

General approach

A cost-of-illness approach was used and the principle adopted was to identify opportunity costs*. Wherever possible valuations were explicit and care was taken to avoid double counting. Market prices were used in the valuation of resources, eg. EHOs investigation time, medicines etc. No attempt was made to apportion capital costs of institutions, eg. EHDs and hospitals, which are involved in multiple and varied activities. To apportion costs of the public health infrastructure would have involved a different type of study outside the scope of this thesis. Where market prices were not available implied values were used as a proxy measure of resources. Where alternative valuations were available both or a range of values was presented, providing a minimum and maximum cost. The method and source of valuation for each area of cost is discussed under the relevant section.

Description of the survey

The survey was carried out in collaboration with EHDs in England and Wales. A list of the names and addresses of all Chief Officers (CEHOs) was provided by the Institution of Environmental Health Officers. Letters inviting the collaboration of CEHOs, and including the study protocol and a sample questionnaire, were distributed in August 1988. A similar pack was sent to all MOsEH and PHL Directors. The protocol was submitted to the President of the Faculty of Community Medicine, The British Association of Community Physicians and the Institution of Environmental Health Officers for comment (a copy of the summary protocol and questionnaire are included in Appendix 4b).

The questionnaire was developed from a cost-study in Birmingham in 1986 which was designed to identify and quantify the use and costs of health care services utilised by cases of **S. typhimurium** and campylobacter infection (Sockett and Stanwell-Smith, 1986). The study showed the feasibility of obtaining detailed information on health service use.

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*The advantages of the cost of illness approach in this type of study are discussed in Chapter 2.

A development of the questionnaire including questions about costs to the affected individual was piloted during a campylobacter outbreak in Dorset with encouraging results (Sockett and Pearson, 1987).

Two pilot studies were conducted in Spring 1988 following a nationwide salmonella outbreak (Pilot A), and to confirmed sporadic cases in Bristol (Pilot B). Both pilots were used to test the final contents of the questionnaire and, in pilot B, the methods of administration and return. A response rate of 67% was obtained in Pilot A and improved to 81% by follow-up of non-responders. The response rate was 60% in Pilot B without follow-up. The lower rate in Pilot B indicated the importance of following-up non-responders. One section of the questionnaire, relating to scoring of illness severity, was completed by less than 50% of respondents and was modified in the final version. A detailed appraisal of patient response to the questionnaire based on replies to Pilot A is given in Appendix 4c.

Method of administration

Questionnaires were distributed according to the population of the NHS Region as a proportion of the population, and then proportionately by the population of each participating district within Region. Details of participating local authorities and questionnaires distributed are given in Appendix 4d. Based on 1987, it was estimated that a sample of 5% of reports expected during the study period would include the serotypes which accounted for 95% of reports to CDSC since 1980.

EHOs were asked to pass a questionnaire and letter explaining the purpose of the study (and a prepaid addressed return envelope), to all cases of laboratory confirmed salmonella infection which came to their notice during the study period. This was irrespective of age, sex or severity of illness. Thus, a case was defined as any person with laboratory confirmed salmonella infection (excluding **S. typhi** or **S. paratyphi**) reported to the EHD between 1 August 1988 and 31 March 1989. EHOs were asked to continue reporting until they had used up their quota of questionnaires or until the study period expired, whichever occurred first. This approach was adopted to capture as representative and large a sample as possible, and to limit, as far as possible, any tendency to select particular groups or individuals.

The questionnaire was in two parts linked by a common study number and was sent to participating EHDs in September 1988. Part A was to be retained by the EHO to be returned when investigation of the case was completed. Part B was to be passed to the case at the end of the EHOs investigation and returned direct by the case when symptoms had ceased.

Non-responders

Non-responders were identified by receipt of Part A without a Part B in the following eight weeks. Non-responders were sent a reminder letter with a replacement Part B. No further follow-up was undertaken.

Questionnaire coding and data entry onto computer

The questionnaire was largely self coded except for questions about job, family relationships, social class and incidental expenditure. A 10% sample (150 randomly selected questionnaires) was analysed for coding and data entry errors and failure to answer questions. Error rates of 1% (range 0.1% - 1.4%) for coded information and responders errors were detected. Information was omitted in 0% to 7% of possible entries and was highest in patient entries. Altogether 75 (50%) questionnaires had 1 to 7 errors (average 1.7) (Appendix 4e). Although the overall error rate was about 1%, a high proportion of errors were in key areas. To minimise this all questionnaires were checked for errors and data entry was verified by on-screen review. Finally, the data set was analysed for duplicate entries and coding inconsistencies.

Parts A and B of the questionnaire were linked by a common study number ascribed before distribution. Check questions were incorporated in part B to allow the accuracy of answers to be assessed (eg. answers to questions 2.1 and 5.1 should be the same). Where inconsistencies were detected the lowest answer was adopted to avoid overestimation.

Structure of the questionnaire

The questionnaire was in ten sections, some of which could be omitted if not relevant, and arrows were used to lead the respondent through.

Part A

This part of the questionnaire was designed to identify the amount of time spent on investigations by EHOs, and the grade of staff involved to enable the time-cost of investigation to be calculated. Other local authority expenditure relating to travel costs, administration and compensation costs were also explored. Laboratory costs were based on the numbers of specimens submitted for testing for cases and contacts and for food and environmental samples. Questions about the type of case (sporadic or outbreak associated) were also included.

Part B

The case questionnaire was divided into ten sections as described in Appendix 4b). Where appropriate the effects of the infection on the family and friends of the case were explored to enable as wide as possible a description of the costs of salmonellosis to be made.

Analysis of the survey data

Analysis of the data

The methods of data analysis are described under the main subheadings used in the results section. In each section the approach to the analysis, including use made of supplementary data and their sources, is described. The general approach was to present actual data, or rates derived from that data. Statistical analysis was used to test the significance of certain comparisons or specific hypotheses generated by the data. Statistical significance of specific results was assessed using chi-square or t-tests using a 5% significance level (two-tailed) unless otherwise stated (Armitage and Berry, 1971).

Where extrapolation or modelling was performed the assumptions and approaches used are described in detail. Such descriptions were usually given in this methods section, or were incorporated in the results section if this was thought necessary to understanding the data presented.

Data management and analysis

Storage, management and analysis of the data was performed in Epi Info (Dean et al, 1990). This is an integrated series of programmes designed for management and analysis of data in questionnaire format. Epi Info, GLIM (see Chapter 3) and Minitab (Minitab Incorporated, 1989) were used for statistical analysis of the data.

Response to the survey

The number of questionnaires distributed was the total of all Part A only, Part B only and Parts A+B together returned and the response rate by cases, after excluded questionnaires were removed, was therefore:

$$\frac{\text{Total part B}}{\text{Total parts A only + B only + A\&B}} \times 100$$

A total of 119 questionnaires were excluded on the basis that onset of illness was outside the study period (52), infection was due to agents other than salmonellae or by **S. typhi** or **S. paratyphi** (2), the questionnaire was either not completed, was unreadable or a duplicate (65). The response by local authorities was assessed by the number which returned completed questionnaires.

Representativeness of sample

Representativeness was explored by comparison of age, occupation, social class, ethnicity, and regional distributions in the sample, with the population of England and Wales and laboratory reports of cases over the study period and the significance of differences tested. Comparisons between the sample and all salmonella isolations reported to CDSC were made on the basis of date of onset of illness, prevalence of serotypes and type of case (ie. sporadic or outbreak associated).

Population statistics and information on ethnic and social class distribution were extracted from Population Trends (OPCS, 1988). Data relating to salmonella isolations in England and Wales was derived from laboratory reports to CDSC. The social class of cases in the study was allocated according to job and employment status of the main wage earner in the household and was based on the classifications given in Classification of Occupation (OPCS, 1980).

Local authority investigations

Costs of local authority activities were estimated from an analysis of time spent on investigations and associated travel and administration costs, and compensation payments to individuals excluded from work. Staff costs were calculated from information about the grade of staff and time spent on investigation applied to the relevant point on the salary scale. These were further adjusted to take into account costs of employment. Aggregated data for the various grades showing details and value of time are shown in Appendix 4f. Travel, administration and exclusion compensation costs* were extracted directly from the questionnaire.

Laboratory investigations

Estimated numbers of faecal specimens tested for cases was calculated from information given about the numbers of specimens taken by EHOs plus an assumption that each case had at least one positive specimen taken from which they were identified for inclusion in the study. Information on numbers of specimens from case contacts, foods and environmental sources was sought in the questionnaire.

Costs of laboratory examination for salmonellas (£7.10 per specimen), incorporating staff time and consumables, were derived from previous estimates expressed as 1988 prices (Roberts et al, 1989). Additional costs for reference laboratory confirmation of serotype and phage type were estimated on the assumptions that either at least one isolate from each individual and item was submitted, or every positive isolate was submitted to the Reference Laboratory. The cost per culture of £15.00 for referred specimens was supplied by Dr B. Rowe (Director, Laboratory of Enteric Pathogens, CPHL, Colindale; personal communication).

Costs to the health sector

Demand for services by age and social grouping were analysed and differences were tested for significance. Medical costs were based on the use of GP, hospital and ambulance services derived directly from the questionnaire. Total use of these services was expressed as the numbers of GP consultations, visits to A&E and OP departments and numbers of days in hospital. Costs of a day in hospital for an acute medical admission and use of A&E and outpatient (1988 prices) were derived from Hospital Costing Returns for 1988 updated using the price index provided by the DoH (Economic Advisors Office, DoH, personal communication).

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*Exclusion compensation was calculated by local authorities as the difference between expected average earnings by the case less payments by the employer. Compensation was paid under the Public Health (Control of Diseases) Act, 1984. These are, however, transfer payments between LAs and individuals; as such they are not included in aggregated national costs but are shown to indicate the impact of salmonellosis on LAs. The compensation payments represent 2.2% of the minimum estimate of lost production.

The estimated costs these gave were:

Cost per day for an admission	:	£119.33
Cost per visit to A&E, 1st visit	:	£ 28.41
Cost per visit to A&E, subsequent	:	£ 23.22
Cost per visit to OPD, 1st visit	:	£141.22
Cost per visit to OPD, subsequent	:	£ 33.08

Ambulance costs were estimated with the help of the York Ambulance Service (York Ambulance Service, personal communication; National Ambulance Service Survey 1988-89, 1990) and incorporated differential costs between emergency admission (£27.50) and discharge by 'bus' ambulance (£7.00). It was assumed that all admissions by ambulance were emergency admissions and all discharges were by 'bus' ambulance.

The impact of salmonellosis on general practice was estimated from demand for GP consultations. Distinction was made between surgery and home consultations on the assumption that the associated costs would be different. Payment of GPs in the UK included a capitation fee for registered patients, practice allowance and fee for service. In order to identify, as closely as possible, the cost of a consultation, advice was sought from the DoH and the BMA (personal communication). To allow for the difference in the doctors time required differentiation was made between home and surgery consultations and figures which approximated to the cost of a surgery consultation (£7) or a home visit by a GP (£14.95) at 1988 prices were derived.

Costs of prescribed medicines to the NHS were calculated from questionnaire data giving the number of items received and whether the case paid prescription charges (Anon, 1985b). The estimated average cost of prescribed medicines obtained from DoH cost data for 1988 was £6.33 per item and this was adjusted to take into account patient contributions so as to avoid double counting.

Costs to patients and families

The principle used to assess costs to patients was to estimate how much it would cost to place them in the position in which they would have been had the infection not occurred. It was not assumed that these costs represented the value patients would place on avoiding illness, however, they do represent some minimum value of benefits*. Attention was given to identifying and quantifying costs to family and friends.

Costs associated with medical treatment included travel related to seeking treatment, delivering specimens and visiting relatives, prescription charges and expenditure in hospital. It was recognised that some expenditure in the last category may be compensatory but it was assumed this represented a true opportunity cost since the money may have been spent in other ways had the individual not been admitted.

The costs of travel to the GP and hospital by cases were estimated from the number of journeys made and the method and distance of travel. Two approaches were taken to the costing of these journeys. The first was based on the assumption (Assumption 1) that all journeys were costly irrespective of the method of travel and the public transport rate (16.47 pence per mile) was applied to all journeys. The second approach (Assumption 2) was to apply differential rates to journeys by car and cab or taxi (27.07 pence per mile, public sector car allowance) and to journeys by public transport (16.47 pence per mile). Journeys by foot or other or not stated means were excluded. The mileage rates used were based on public sector travel allowances (PHLS Finance Department, personal communication). Accompanying persons were assumed to have used the same method of travel as cases but the costs were two pence per mile for journeys by car under Assumption 2. The full public transport rate was applied to all journeys under assumption 1 and for journeys by public transport under Assumption 2.

Costs relating to expenditure on prescribed medicines were based on information in the questionnaire on the number of items purchased by individuals not exempt from charges. The number of such items was multiplied by the then current (1988/89) contribution of £2.60 per item. This was costed separately from the estimated NHS expenditure on prescribed medicines to avoid double counting. Information was sought about expenditure associate with hospital in-patient stay and visits to

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*It could also be argued that a profile of costs and the physical impact of the illness should be provided as background information in studies which attempt to ascertain benefits using the "willingness to pay" approach.

OPDs. Details on such expenditure were categorised under clothing and toilet articles, leisure items, dietary items and other.

Other costs incurred by cases and families and resulting from illness in an individual were explored under two headings. The first, 'additional expenditure' related to items or services purchased in order to obviate the effects of illness. These were analysed under the headings: medicines and medical care (ie. purchase of over the counter remedies and private medical care); communications; hygiene materials; food and drink; clothing and bedding; leisure items; other. The second covered 'unexpected consequential losses.' These were categorised under cancelled or postponed arrangements; pre-paid education fees; interrupted holiday arrangements. Information on compensation claims through insurance of these items was not sought except for interrupted holidays, and no prompting was given as to the types of losses incurred other than those relating to medicines and telephone expenses.

To estimate personal losses associated with illness abroad it was assumed, first, that individuals valued a day's holiday at least as much as they had paid for it. This was estimated at £28 per day for an average length holiday of 10 days (Carol Dunn, Thomsons Tour Operators, Advertising, market research and press office; personal communication). Second, that loss varied with the level of limitation on activity and the following arbitrary allowances were made. Thus a day confined to bed was valued at £28; being up but confined to residence was also severely limiting although may have allowed some utility to be derived, and was valued at £21 per day. Being able to go out although feeling unwell may have been only slightly limiting and was valued at £7 per day. No information was sought about the limitation on activities imposed on relatives and friends who stayed to care for cases; however, it was assumed they were at least as great as for cases confined to their hotels and were also valued at £21 per day. Individuals were asked to indicate if compensation for holiday related losses was claimed. However, because of the potential delays in negotiating such claims details were not requested for this study.

Lost productivity

Time off paid employment by patients and those who cared for them was taken to approximate productivity loss. Distinction was made between those in full-time, and those in part-time employment, although production loss was calculated from the total time off work. Lost production was calculated using estimated average earnings for men and women for the period of the study and adjusted for labour costs (DoE, 1990). These were presented as minimum and maximum costs depending on the approach used. Thus minimum costs were calculated using gender specific rates for men and women (male rate: £49.26; female rate: £33.77); for maximum costs a single rate (£43.75) removing the differential payments to men and women was used.

Intangible costs

The methods for valuing intangible costs, which for this study were taken to include value of lives lost, pain and suffering, loss of leisure, schooling and housewives time, are not necessarily well developed. Where possible valuations were based on methodologies employed in published works. If these were not available or not well developed possible surrogate measures were suggested. Where appropriate estimates were adjusted to incorporate the possible effects of different assumptions or different value systems.

Loss of life

The approach adopted was to present a range of estimates based on the main methods employed for valuing life (see Chapter 2). These included implicit value of life (VL), values based on the human capital (HC) approach and values based on willingness to pay (WP) estimates. This approach was similar to that adopted by Cohen (1982), Yule et al (1986) and Roberts et al (1989). The average values used in this analysis were derived from these studies. A fourth approach, that of Landefeld and Seskin (1982), which adjusted HC values to include values of non-labour income and risk reducing activities, was also compared. The values of life as applied to this study sample were further adjusted to take into consideration the age and health of the cases who died and for whom average costs would have clearly been inappropriate, and the estimated degree of relationship between salmonella infection and death.

Estimates of the number of lives lost annually in England and Wales due to salmonella infection were based on registered deaths (Chapter 3).

The values of life applied to these totals were adjusted to incorporate assumptions about the relative contribution of salmonella infection to death of the individual and for the age of the patient. A survey of all cases reported to CDSC to have died with a salmonella infection in 1983 showed that in 60% salmonellosis was, in the view of the attending physician, the cause of death. In 20% it was reported to have contributed to, but not to have been the cause of death, and in a further 20% salmonella infection was unrelated to death or its relation was not known (unpublished data). A matrix showing the value of life for each level of association of salmonella infection with death, weighted for the average proportionate life expectancy within age bands, was constructed (Appendix 4g). This assumed 100% of the value of life where death was caused by salmonella infection, 50% where it was contributory and 1% for the remainder. A similar matrix showing the proportionate distribution of deaths by causal relationship and age was constructed from average data on salmonella deaths over the period 1985 to 1989 (Appendix 4g). This enabled the annual number of cases to be estimated for each cell and the value of life to be calculated.

Loss of normal activities

Two approaches were taken to estimate the value of loss of normal activities which were related to the degree of restriction caused by illness. No attempt was made to obtain estimates from individuals which would reflect the subjective value they would place on avoiding salmonella infection. To have done so would have required an extensive and different type of study; however, in attempting to value these important effects two surrogate measures were used. The first was based on estimated costs of serious and slight casualties in road traffic accidents as described by the DoT. This included a notional sum equivalent to 75% of the total for the costs of pain and suffering (DoT, 1990; Mrs McMohan, DoT, personal communication). This approach was similar to that utilised by Cohen (1982) and Roberts et al (1989). The costs of a serious casualty, defined as a person requiring one or more nights in hospital, were £16,723, of which pain and suffering was £12,613. Similarly, the costs of a slight casualty, i.e. all other cases, was £342, of which pain and suffering was £221.

The second approach was based on that adopted by Krug and Rehm (1983) and Curtin (1984); estimated leisure time lost was applied to a surrogate value of leisure. Hours of leisure time lost in this study was calculated from the number of days ill and assumed five hours leisure time per working day and 12.5 hours per day at weekends, thus:

$$\text{Hours of leisure} = (\text{days ill} \times 5/7 \times 5) + (\text{days ill} \times 2/7 \times 12.5)$$

Further adjustment was made on the assumption that the amount of leisure time lost varied with the degree of restriction imposed by illness and was thus:

100% for all in hospital
50% for those confined to home
10% for those unwell but able to go out
0% for those infected but not restricted

No adjustment was made for age or sex of the case and it was assumed that leisure time should be valued at least as much as employment remuneration and was therefore based on average hourly wage rate (£5.75, not gender adjusted) (Krug and Rehm, 1983; Curtin, 1984).

Loss of schooling

To estimate the value of lost schooling it was assumed that the value of a day's school was at least that of inputs into education as indicated by that which the government allowed, on a per capita basis, for education, and that children would be kept off school for the total length of their illness. The per capita allowance was £1,100 for nursery and primary age children and £1,690 for secondary age children for the school year 1988-89 (DES, personal communication). These figures were divided by the number of schooldays in a year (190) to give a daily value (£5.79, primary; £8.89, secondary). These figures included allowance for running costs of the school (eg. consumables, basic maintenance and staff salaries), but excluded school dinners or any capital costs. To estimate school days lost the total length of illness was multiplied by 5/7. Totals were then adjusted to incorporate assumptions about school holidays.

Loss of housewives time

The number of housewives in the sample was assumed to include all women who designated themselves as such, women retired from paid employment and unemployed women. Women in paid employment were considered separately. To calculate loss of productive output from housewives two assumptions were made. First, that housewives' time is valuable and worth at least as much as the average cost of employment for women. On this basis the gender adjusted average daily rate for a woman in full-time employment of £33.77 was used to estimate costs. Second, that loss of activity was 100% for women admitted to hospital or confined to bed at home, 50% for women ill at home but able to get up or go out, and 0% for those infected but otherwise unaffected. It was felt that a sum should be included for working women who would carry out housework tasks at other times, including evenings and at weekends. A notional amount of half the rate was allowed for women in part-time employment and 5% of the rate for women employed full-time. These sums were adjusted to take into account the degree of loss of activity.

Estimated costs of human salmonellosis in England and Wales in 1988

In extrapolating the results of the study to estimate the annual costs of human salmonella infection in England and Wales it was necessary to make assumptions about levels of under reporting of illness and the severity of illness and its associated costs.

Numbers of cases

Estimates of the level of under reporting were obtained from Sockett and Roberts (1989) and were derived from a MAFF survey of experience of gastroenteritis in the community in 1988 (MAFF, 1988), and assumptions about the likely source of infection based on distribution of causal organisms in laboratory reports of gastrointestinal illness to CDSC (see Chapter 3). Thus it was estimated that 1/38 of actual cases and 1/6 of treated cases were reported centrally.

Severity of illness

Two approaches were taken to estimate annual costs for England and Wales which incorporated alternative methods for relating costs to severity of illness. The first ranked severity according to the level of treatment demanded and applied average tangible costs for each demand group. These were aggregated to estimate annual costs. The sample was divided into four demand groups: those requiring hospital treatment, those requiring at least one home visit by a doctor, those who had surgery consultations only and those who did not see a doctor. To test the robustness of this assumption the average length of illness and time off work was compared for each group.

The second approach categorised severity according to a subjective assessment, by the case, of how ill he or she was. This assumed that demand for treatment was patient led. A severity index was constructed from answers by individuals to questions, about which symptoms they experienced. Patients were invited to score each symptom according to whether they thought it was mild, moderately severe or severe (scoring 1, 2 and 3 respectively). A "symptom index" was then calculated by adding the scores for each patient's symptom and dividing by the number of symptoms, in effect giving an average score. Therefore the greater the index the more severe the illness experienced. These were arbitrarily divided into six groups: 1 (index <1); 2 (index 1-1.4; 3 (index 1.5-1.9); 4 (index 2.0-2.4); 5 (index 2.5-2.9); and 6 (index = 3). As with Approach 1 the robustness of the symptom index was tested by comparing the average length of illness and use of medical services for each group. The rank correlation coefficient (Spearman's rank correlation coefficient r_s: Snedecor and Cochran, 1967) was calculated to determine the strength of the relationship between index groups and variables (see Appendix 4h). Estimated total and average costs for the study sample were calculated for each severity group.

Total national tangible costs for 1988, as with Approach I, were estimated from average costs for each category. Costs for reported cases were calculated by multiplying estimated cases in each index group by the average cost per case for each category for each index group. Costs of treated but unreported cases were estimated by applying average overall costs per case for each category to the number of cases. Calculating costs for untreated and unreported cases was more complex. Since most of these cases were likely to be mild, average costs for index group 1 were used but were adjusted to remove public sector costs and production losses associated with exclusion from work. This was done on the assumption that, even if the cases worked in an "at risk" occupation (i.e. food handler), if they were not known to have salmonella infection they would not be excluded from work.

RESULTS

A total of 1,601 questionnaires were distributed; 119 were excluded (see Methods) and the results presented are, therefore, based on the remaining 1,482 questionnaires.

Response to survey

Of the 1,482 questionnaires returned, 1,229 included patient-completed Part B, indicating a response rate by cases of 83%. This included 67 patients who responded to the reminder letter. This result was slightly better than the best pilot study (81%). Over half (237) of the 404 local authorities in England and Wales agreed to participate in the study, and questionnaires accepted into the study were returned from 200 of these. Almost two thirds (65.4%) of patients completed the questionnaire within eight weeks of becoming ill and over 90% within six months. In 8.8%, the lag period was greater than 24 weeks.

Characteristics of sample

Description of the characteristics of the sample included an analysis to examine its representativeness of laboratory reports of salmonella infection to CDSC and of the population of England and Wales.*

Distribution of cases

The population of the local authorities from which the study was drawn was 27.04 million, 54% of the estimated population of England and Wales. The number of local authorities in any region from which questionnaires were returned varied between a third and four fifths and the proportion of the region's population from which cases were drawn varied between 26% and 89%. The proportionate distribution of questionnaires returned and the distribution of population by region were similar (Appendix 4d), although the difference was significant ($P < 0.001$). A similar result was obtained when laboratory reports to CDSC by region for the period of the study were compared and were found to show significant variation from the study sample ($P < 0.001$).

Date of onset of illness

Information about date of onset of illness was available for 1,266

* LAs were asked to survey all cases of confirmed salmonella infection reported to them. However, the study did not specifically identify infections acquired in institutions, eg. hospitals, and these were not explored per se.

patients. Of these, 87% were ill in the period July to December 1988 and the remaining 13% in the first three months of 1989. This distribution was similar to that of laboratory reports, by month of receipt, received by CDSC for which 84% of reports were received between July and December 1988 and 16% in January to March, 1989.

Serotypes recorded

The specific salmonella serotype identified was recorded for 745 cases. Most were **S. enteritidis, S. typhimurium** or **S. virchow**. This was not significantly different from the distribution of salmonella serotypes reported to CDSC during the same period (Table 4.1).

Type of case

Most, 875 (59%), cases were sporadic and 423 (28%) were part of family (285 cases, 19%) or general outbreaks (138 cases, 9%). No information was given for the remaining 184 (12%). The proportion of outbreak-associated cases was higher than for laboratory reports to CDSC for the years 1988 and 1989 (9% and 15% respectively). However, the annual CDSC totals may not be comparable with the sample because of the different time periods covered; also the inclusion of large outbreaks in the sample may have resulted in over-representation of cases in this category. Data presented in Chapter 3 suggested family outbreaks are under-ascertained by CDSC; the high proportion of outbreak associated cases identified in the sample was a result of detailed questioning.

Age and sex of cases

The age and sex distribution of cases in the sample are shown in Table 4.2. There were more females (55%) than males (45%) in the sample, due to an excess of females aged 15 to 64 years. Proportionately, the age distribution of the sample was similar to the age distribution of all salmonella cases reported to CDSC in 1989 and salmonella isolates referred to the DEP for confirmation. Cases aged under one year or >65 years were under-represented; when these age groups were excluded there was no significant difference in the remaining age groups when the sample was compared with either laboratory reports or referrals to DEP. The sample showed significant differences when compared with the age distribution of the population of England and Wales, exhibiting an excess of children aged under five years, whereas the elderly (aged >65 years) were under-represented (Appendix 4i).

Table 4.1

Comparison of Distribution of Serotypes in Study Sample with Reports to CDSC During Study Period from Laboratories in England and Wales

Serotype	Number and proportion (%) of identifications			
	Study sample		Reports to CDSC	
Salmonella enteritidis	451	(60.5)	11,999	(58.8)
S. typhimurium	156	(20.9)	4,373	(21.4)
S. virchow	30	(4.0)	812	(4.0)
Other serotypes	108	(14.5)	3,219	(15.8)
Total	745	(99.9)	20,403	(100.0)

Table 4.2

Age and Sex Distribution in Study Sample

Sex	Age group (years)								Total
	<1	1-4	5-9	10-14	15-44	45-64	≥65	Not stated	
Male	23	81	41	19	249	91	39	10	553
Female	23	77	38	19	333	132	38	12	672
Unknown	-	1	-	1	-	-	-	2	4
Total	46	159	79	39	582	223	77	24	1,229

Proportionate Distribution

	Age group (years)						
	<1	1-4	5-9	10-14	15-44	45-64	≥65
Sample	3.8	13.2	6.6	3.2	48.3	18.5	6.3
Laboratory reports to CDSC	6.1	12.5	5.9	3.7	47.0	16.0	8.8
Reports to DEP	4.5	15.0	6.9	4.0	46.6	14.7	8.3

Length of illness

Details of the length of illness were obtained from 1,151 cases (517 males, 631 females, 3 sex not known) who were ill for a total of 21,380 days. This gave a mean length of illness of 18.6 days (median length of illness 12 days; range 1-254 days) (Table 4.3). The average length was however affected by 38 (1.5%) cases with illness lasting over 63 days (9 weeks) and accounting for 17% (3,660 days) of total days ill. Removing this group reduced the average length of illness to 15.9 days.

Females were ill slightly longer (average 19.2 days) than males (average 17.9 days). Stratifying by age showed that males aged under 10 years were ill slightly longer than females. Median length of illness showed less variation between the sexes and the differences were not significant. In males and females average and median length was lowest in children aged 5 to 9 years and highest in those aged 10 to 14 years.

Ethnic origin

Although questions about ethnic origin were not included in the questionnaire the representation of ethnic minorities was inferred from the patient's name. In the sample 2.6% (37) cases in England (5.4% in the population) and 1.3% (1) case in Wales (1.2% in the population) had ethnic minority names. Thus ethnic minorities were under-represented in the sample for England by 50%. This approach was likely to be inaccurate because of the small sample and because estimates based on family name would not include individuals from minority groups with English or European names. The geographical distribution of local authorities would have been less likely to affect results, since areas with large ethnic minority populations were represented.

Social grouping

Insufficient details were available to classify 546 cases. The distribution of the 936 remaining cases and of 75 men aged 45-64 years only is shown in Table 4.4. These showed a significant difference ($P < 0.001$) when compared with expected values for England and Wales. Social groups I to IIIN were over-represented in the sample and groups I and II were over-represented in the sub-group of men aged 45-64 years only. Analysis of the age distribution within social groups showed more variation than would be expected from random effects alone, however, no group stood out from this background noise.

Table 4.3

Average and Median Length of Illness (in Days) by Age Group for Males and Females

	Age group (years)										All ages
	0–4	5–9	10–14	15–24	25–34	35–44	45–54	55–59	60–64	≥65	
Males											
Average	17.0	14.5	26.4	16.7	25.1	14.6	15.6	13.6	19.2	15.8	17.9
Median	9	8	19	14	16	11	14	11	11	9	14
Females											
Average	13.9	12.9	29.8	20.3	18.5	21.7	20.0	22.7	16.4	20.6	19.2
Median	10	8	18	14	14	14	14	15	10	14	13
All											
Average	15.4	13.7	27.9	18.8	21.5	18.7	18.4	18.2	17.8	18.2	18.6
Median	10	8	19	14	14	12	14	14	11	12	12

Table 4.4

<u>Comparison of Social Group Distribution in Sample</u>
<u>with Population of England and Wales</u>
(percentage distribution shown in brackets)

	Social group					
	I	II	IIIN	IIIM	IV	V
Study (observed):						
all cases*	75 (8)	280 (30)	142 (15)	266 (28)	146 (16)	27 (3)
men aged 45-64 years	9 (12)	27 (36)	8 (11)	23 (31)	7 (9)	1 (1)
Expected†:						
all cases	46 (5)	219 (23)	97 (10)	312 (33)	166 (18)	57 (6)
men aged 45-64 years	4	18	8	25	13	5

* no information for 546 records

† Source: Population Trends, spring 1988; based on social class distribution of men aged 45-64 years in 1981 (1980 classification).

Occupation
Details of occupation were given for 1,223 cases (Table 4.5). The sample included 665 adults in full- or part-time employment. A further 23 persons of employable age were classified as unemployed. Of the 95 women described as housewives, 15 were aged over 60 years (age not stated, 2 cases). School children and students accounted for 158 cases, and 198 cases were pre-school children.

There was no significant difference between the proportions of men and women, of employable age, in full time employment in the sample (92% of men and 61% women) when compared with the population of England and Wales (78% men and 66% women) (DoE, 1992). Although this result was based on a relatively small sample.

Illness acquired abroad
Twenty per cent (303) of cases were ill abroad or within a few days of returning home. No information was available from CDR reports in 1988 for travel-associated infection; however, data presented in Chapter 3 suggested this proportion was slightly above that recorded by the DEP and for reports to CDSC in 1989. The numbers do, however, vary during the year, being highest between June and November. This may have affected the distribution of the sample which was dependent on reports received largely during the summer and autumn of 1988. Most (178, 59%) cases had been to Europe, in particular Spain and the Balearic Islands (108, 36%), or North Africa (73, 24%). This distribution probably reflected the popularity of these resort areas (see Chapter 3). The possibility that persons with a recent history of travel abroad were more likely to be asked to submit a specimen for laboratory examination may have accounted for the high proportion of such cases.

Public Sector Costs

Local authority investigations

Local authority costs were between £85,633 and £94,393 and costs per case, based on 1,482 cases, were calculated at between £58 and £64. However, average costs, based on the numbers of cases for which details were given were considerably higher. In particular financial support for individuals excluded from work was on average £295 (Table 4.6).

Status or Employment Category of 1,223* Cases

Status/ employment group	Sex			Total
	Male	Female	Not stated	
Pre-school child	104	93	1	198
School child	65	74	-	139
Student	9	10	-	19
Employed full-time	311	202	-	513
Employed part-time	6	146	-	152
Housewife	-	95	-	95
Retired	45	39	-	84
Unemployed	11	12	-	23
Total	551	671	1	1,223

* no information available for 259 cases

Table 4.6

Costs of Local Authority Investigations

Cost category	Total (£)		*Cost per case (£)		†Average cost (£)	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Staff time	54,685.44	63,445.86	36.90	42.81	41.65	48.32
Travel	14,177.26	14,177.26	9.57	9.57	12.31	12.31
Administration	4,767.72	4,767.72	3.22	3.22	4.67	4.67
Employment exclusion	11,494.41	11,494.41	7.76	7.76	294.73	294.73
Not stated	507.86	507.86	0.34	0.34	42.32	42.32
Total	85,632.69	94,393.11	57.79	63.70	395.68	402.35

* 1,482 cases

† number of cases giving details in each category

Staff costs

Of 960.6 days spent on investigations (average 0.73 days, based on 1,313 questionnaires), most were associated with investigation by Technical, Basic and Senior EHO grades, who accounted for most of the costs (£54,685 minimum). In addition, a further 154.9 days were recorded for which no grade was specified; if these were included on the assumption that the distribution of grades was the same, then maximum costs of staff time would have been £63,446 (Tables 4.6, 4.7).

Travel costs

Travel costs associated with investigation of cases, including interviews, inspections, and collection and delivery of specimens, was £14,177.26 for 1,152 cases (range £0.12 - £400) (Table 4.6).

Administration

Administration costs were £4,767.72 for 1,021 cases; these included costs of consumables related to postage, telephone, photocopying, etc. The range of costs varied widely, from a few pence to £241 (Table 4.6).

Exclusion

Thirty-nine persons were compensated following exclusion from work at a total cost of £11,494.41 (range £22.15 - £2,215) (Table 4.6).

Other, not stated

£507.86 costs associated with 12 cases were recorded for which no details of the category of cost were given (range £0.86 - £400).

Laboratory investigations

An estimated 6,614 specimens were submitted for bacteriology; 71% by cases and 26% by contacts. Only 3% were for food or environmental testing. Routine costs were calculated at £46,959.40 (Table 4.8). Estimates of the costs of reference laboratory confirmation of serotype or phage typing based on two assumptions were £24,570.00 (at least one positive isolate from each individual or item was referred) and £49,875.00 (every positive isolate was referred). This gave a range of £71,529.40 to £96,834.40 for laboratory tests (Table 4.8).

Table 4.7

Length and Estimated Costs of Investigations by Environmental Health Officers

Grade of staff		Length of investigation (days)	Estimated costs of investigation (£)*
Clerical and administrative		117.3	3,298.57
Technical grades		278.0	11,733.60
EHO grades:	Basic/Senior	518.2	28,780.50
	Principal	47.1	3,616.16
Total		960.6	47,428.83
Total including labour costs†			54,685.44
Grade not stated		154.9	7,597.94
Total including labour costs†			8,760.42
Grand total		1,115.5	55,026.77
(including labour costs)†			63,445.86

* at 1988/89 rates; † charges for labour = 15.3% of total costs

Table 4.8

Costs of Laboratory Tests for Salmonella

Laboratory test	Number of specimens		Minimum cost (£)	Maximum cost (£)
Routine examination for salmonellas -*				
cases	4,687		33,277.70	
contacts	1,695		12,034.50	
foods	193		1,370.30	
environment	39		276.90	
Total	6,614	Sub-total	46,959.40	
	Cases or items	Positive for salmonella		
Reference laboratory confirmation† -				
cases	1,482	2,736	22,230.00	41,040.00
contacts	146	572	2,190.00	8,580.00
foods	7	14	105.00	210.00
environment	3	3	45.00	45.00
Total	1,638	3,325	24,570.00	49,875.00
Total cost			71,529.40	96,834.40

* estimated at £7.10 per specimen; † estimated at £15.00 per culture

Costs to the Health Sector

Medical costs to the NHS for 1,229 cases were calculated as £235,659.56 and included hospital treatment, GP services, the ambulance service and net costs of prescribed medicines to the NHS (Table 4.9). The total was very sensitive to the costs of in-patient hospital care, which were £761.71 per case compared with an overall cost per case of £191.75.

Use of medical services was explored for differences in demand by age and social grouping (these are tabulated in Appendix 4j). Average length of time in hospital, for those admitted, increased with age and was highest in cases aged ≥45 years. There was little variation in the average use of other services with age. Proportionately, the highest use of services was in age groups 0 to 4 years, 10 to 14 years and the elderly. Analysis by social group indicated that average time in hospital, and average numbers of outpatient visits and surgery consultations were highest in social group 5, and average numbers of home GP consultations in group 3M. When subjected to statistical analysis there was no significant difference in demand for services by age or social group. A more detailed analysis of each category of treatment service is given below.

In-patient treatment

Altogether 227 (18.5%) respondents were admitted to hospital for an average stay of 6.4 days (Table 4.10). The length of stay, however, varied with age. Thus cases aged ≥65 years of age were in hospital twice as long as children aged less than nine years. A total of 1,449 days in-patient treatment was recorded at a cost of £172,909.17 (1,449 x £119.33), 73% of costs attributed to medical services (Table 4.9). Children were accompanied in hospital by adults who often stayed with them. It was not possible to estimate the cost to the hospital of those who stayed although any costs incurred by the hospital may have been compensated for by parents saving nursing time. This aspect should be further explored.

Accident and Emergency (A & E) visits

A total of 124 cases were seen in A & E departments on 157 occasions at a cost of £4,289.10 (Table 4.9). Most (103) cases visited once and multiple visits were recorded for 21 cases. There was no significant

Table 4.9

Medical (National Health Service) Treatment Costs

Cost category	Number of cases	Days, visits, items, journeys	Unit cost (£)	Sub-total (£)	Total cost (£)	Cost per case (£)
Hospital services:						
in-patients	227	1,449	119.33		172,909.17	761.71
A & E[1] Department	124	124	28.41	3,522.84	4,289.10	34.59
		33*	23.22	766.26		
OP[2] Department	97	97	141.22	13,698.34	16,443.98	169.53
		83*	33.08	2,745.64		
ambulance	101	101	27.50	2,777.50	2,959.50	29.30
		26†	7.00	182.00		
General practice:						
home visits	587	1,230	14.45	17,773.50	31,367.50	27.98
surgery	866	1,942	7.00	13,594.00		
prescriptions‡:						
patient exempt	289	595	6.33	3,766.35	7,690.31	9.95
patient not exempt	484	1,052	3.73	3,923.96		
Total					235,659.56	191.75

[1] Accident and Emergency   [2] Out-patients

* subsequent visits   † return home by "bus" ambulance

‡ net costs to the National Health Service; includes three cases in each group for whom an estimated two items each were prescribed.

Table 4.10

Length of Stay in Hospital by Age Group

Age group (years)	Number of cases	Total days in hospital	Average stay (days)	Median stay (days)
0- 4	63	307	4.9	3.0
5- 9	12	42	3.5	3.0
10-14	12	62	5.2	4.0
15-24	35	238	6.8	5.5
25-44	52	336	6.5	6.5
45-64	28	227	8.1	6.3
≥65	25	237	9.5	7.0
All ages	227	1,449	6.4	5.0

Table 4.11

Numbers and Types of General Practitioner Consultations

Type of consultation	Number of cases (%)	Number of consultations (%)	Average	Admitted to hospital (%)
Home only	263 (23)	594 (19)	2.3	102 (45)
Surgery only	533 (47)	1,207 (38)	2.3	44 (19)
Home + surgery	325 (30)	1,371 (43)	4.2	81 (36)
Total*	1,121	3,172	2.8	227

* a further 16 patients made 71 visits to doctors' surgeries to deliver specimens

Range in number of consultations = 1-29

difference between age groups in the total or average numbers of visits made, although the highest number of cases and visits were associated with children aged up to four years (details of admission by age are given in Appendix 4k.i). Since attendance at A & E departments was costed separately from in-patient care, visits by admitted cases were included. Eighty-six (69%) cases seen in A & E were admitted and accounted for 62% of visits. Fewer multiple visits were made by admitted cases (average 1.14 visits) than were made by cases not admitted (average 1.55 visits). Most (14 of 21) multiple visits were in cases aged ≥10 years, suggesting a greater tendency for young children to be treated as in-patients on first presentation.

Out-patient visits

Ninety-seven cases attended OP departments on 180 occasions at a cost of £16,443.98 (Table 4.9). This included differentiation between the costs of a first visit (£141.22) and subsequent visits (£33.08). Most (55, 57%) cases visited once and 42 (43%) visited two or more times, including one adult on 10 occasions and one teenager on 15 occasions. There was little difference between the average number of visits made by admitted cases (1.9) and those not admitted to hospital (1.8). However, a smaller proportion of cases who had been admitted to hospital made multiple visits (20 of 53 cases, 38%) than cases not admitted (22 of 44, 50%); details are tabulated in Appendix 4k.ii.

Ambulance services

It was assumed that at least one journey per case (101 cases) was an emergency admission, which would account for 101 of the 127 journeys recorded. The remaining 26 journeys were assumed to have followed discharge from hospital and transport was by bus ambulance. This assumption may not be unreasonable, on the basis that illness in 96 of the patients (118 journeys) was adjudged to be serious enough to warrant admission to hospital. There was a large differential in the costs between the two types of ambulance journey, and this is reflected in the total calculated costs of £2,959.50 (Table 4.9).

General practice

A total of 1,121 patients saw their doctor for 3,172 consultations (average, 2.8) (Table 4.11). Although 86% (959) cases saw their doctor between one and four times, the range of consultations was between one and 29. Surgery visits only accounted for the highest proportion of cases, however, the greatest number and proportion of consultations were recorded in cases who saw their doctor both at home and at the surgery. This group also accounted for the highest average number of consultations. There was no difference in the average number of home only and surgery only consultations. When costs of home (1,230 visits) and surgery (1,942 visits) consultations were applied to the data these gave an estimated cost for the sample of £31,367.50 (Table 4.9).

Costs of medicines (prescriptions)

A total of 773 cases received 1,647 prescription items; this gave an average of 2.1 items per patient (range 1-20 items) for cases receiving medicines (1.3 for all 1,229 cases returning details). The average number of items was greater for cases who had been admitted to hospital (2.6 items) than for cases who had not (2.0). To avoid double counting in calculating the net costs to the NHS, differentiation was made between the 289 (37%) cases (595 items, average 2.1) exempt from prescription charges and the 484 (63%) cases (1,052 items, average 2.2) not exempt. The estimated net cost to the NHS was £7,690.31 (Table 4.9); this gave a cost per case of £9.94 for the 773 cases and £6.26 overall.

Summary of public sector costs

The total public sector costs identified for the sample were between £392,822 and £426,887 (£298 - £321 per case). The total costs of investigation and testing were between £157,162 and £191,228. These totals were sensitive to the numbers of days spent on investigations by EHOs and assumptions about the numbers of specimens submitted for reference laboratory confirmation.

Sixty per cent of the costs (£235,660) were associated with the care and treatment of cases. This included £193,642 (82% of treatment costs) associated with in-patient hospital treatment of 227 cases (including A&E, OP and ambulance services); a cost per case of £853 for these patients alone. The public sector costs were, therefore, sensitive to the number and length of stay of cases admitted to hospital.

Costs to Families and Society

The costs incurred by patients and their families included costs of seeking medical treatment and costs resulting from expenditure on items which would not otherwise have been purchased, or losses which resulted from the individuals inability to take advantage of items or services already purchased. These are considered in detail below.

Costs of obtaining general practitioner services

The direct costs of obtaining treatment from GPs fell into three areas: costs of travel to patients, travel costs of accompanying persons and patient contributions to prescribed medicines. Altogether 966 patients mader 6,385 journeys (3,193 visits) to and from the doctor's surgery at a cost of £1,892.90 (Assumption 1) and £2,261.01 (Assumption 2) (see Methods and Appendix 41). Of these, 4,046 (63%) journeys were to attend consultations and 2,339 (37%) were to deliver specimens. Most (64%) journeys were by private car; smaller proportions being made by public transport (8%) or by cab or taxi (4%). The remaining journeys were made on foot (19%) or by other or not stated means (5%). The distance to their surgery was given by 1,030 cases; the average was 1.8 miles (range <1 mile to 14 miles). A total of 1,069 journeys (468 cases) were reported to have been accompanied. The method of transport was not given for these and they were distributed proportionately the same as case journeys and the same assumptions were applied to costs. The minimum and maximum costs derived from the two approaches were £38.48 and £379.44 (Appendix 41).

Journeys to deliver specimens for laboratory testing accounted for 37% of journeys made (average, 2-3: range, 1-34). Most specimens were delivered to the surgery (1,937 journeys) and a small number (402 journeys) were to pathology laboratories or other destinations. No information was collected on the distance to these destinations, thus journeys were costed the same as the average journey to the GP surgery. This may underestimate these costs since pathology laboratories would be located in hospitals and the average distance to hospital for the sample was greater than the average distance to the GP.

Costs relating to patient contributions for prescribed medicines were estimated at £2,735.20, on the basis of the number of items received by persons not exempt from charges (1,052). This was the largest single item of cost relating to treatment by GPs.

Costs associated with hospital treatment

The direct costs to cases and their families and friends which were associated with in-patient treatment are shown in Table 4.12. These ranged from £9,035.32 to £17,195.63 and costs associated with travel, either by cases or visitors, were the most important element. Although expenditure in hospital (trousseau effect) was relatively much lower, this also represented a significant item of cost to individuals.

Travel

Travel costs by 413 cases to receive hospital services were based on a total of 1,621 journeys (811 visits), excluding those made by ambulance which were included under public sector costs. Most journeys were by private car (73%) and by taxi or public transport (12%). Information about the distance travelled from home to hospital was given by 307 cases and was on average 7.6 miles (range <1-128 miles); excluding 6 instances of travel of 30 miles or more reduced the average to 6.6 miles. Estimated minimum and maximum costs were based on similar assumptions to those used to calculate costs of travel for GP services (see Methods). Between 68% and 81% of total travel costs (£6,314.93 minimum and £14,475.24 maximum respectively) were associated with visiting patients in hospital.

A total of 535 visitors per day were recorded by in-patients (average 2.4 visitors per day); based on an average stay of 6.4 days, this gave a total of 6,848 journeys (3,424 visits). Since information on method of transport for visitors was not sought, journeys were distributed proportionately the same as cases for method of transport and costed under the same assumptions (Table 4.12). Since in many cases it was likely that visitors travelled in groups, the estimated minimum costs were halved (from £8,571.78 to £4,285.89), to avoid excessive overestimation.

Trousseau

Altogether 177 cases detailed expenditure of £2,642.10 during hospital

Family Costs Associated with Hospital Treatment

Expenditure		Total cost (£) Minimum	Maximum
Travel by cases*	(1,621 journeys)	2,029.04†	2,773.04
Travel by visitors	(6,848 journeys)	4,285.89†	11,702.20
		6,314.93	14,475.24
Trousseau:			
clothes and toiletries		1,135.85	1,135.85
leisure items		751.78	751.78
food and drink		593.62	593.62
not stated		160.85	160.85
		2,642.10	2,642.10
Costs in Out-patients Department		78.29	78.29
Total		9,035.32	17,195.63

* excludes journeys by ambulance

† average journey = 7.6 miles at public transport rate of 16.47 pence per mile

Assumptions used to derive travel costs are described in Appendix 4(1) stay (Table 4.13), an average of £14.93 (range <£1 - £66) for the 177 cases giving details (or £11.64 overall for 227 cases), although a half of cases spent less than £10. The greatest expenditure was on clothing and toilet articles, although the most commonly bought items related to leisure activities and included newspapers, books and children's games.

The level of expenditure was only marginally affected by the age of the case, thus 37% of cases spending less than £10 were aged under 10 years; however, this age group also accounted for a third of admitted cases. As might be expected, higher expenditure was more likely to be related to length of stay and, whereas 54% of cases (based on 177 cases giving details) spending less than £10 were in hospital for up to one week, 65% of cases spending over £10 were in hospital for over a week.

Seventy-two admitted patients aged up to nine years were accompanied by an adult who stayed with them (these included 56 cases aged <1 year, nine aged 1-4 years and seven aged 5-9 years). Of the accompanying persons, 29 were in full- or part-time employment, 39 were housewives and four were unemployed (2) or their employment status was not given (2). It was assumed that expenditure resulting from hospital stay was included under "trousseau" details and that time taken off work was recorded as time taken off by carers. Total expenditure in hospital for the 51 accompanied cases for whom details were given was calculated to be £793.60, an average of £15.60 per case. This was slightly greater than the average expenditure of £14.93 for all cases.

Out-patient visits
Similar assumptions to those above were made for persons accompanying cases making 55 of the OP visits (including 29 in full- or part-time employment, 16 housewives and 10 others). However, additional expenditure in out-patients of £78.29 was recorded (Table 4.12); anecdotal information suggested this was largely on food and drink.

Other costs of illness

Cases and their families incurred other significant losses resulting from illness of £82,271.48 (Table 4.14). These represented opportunity costs due to additional expenditure required to cope with the effects of illness, or losses resulting from pre-paid arrangements foregone.

Table 4.13

Expenditure while Receiving Hospital Treatment

Item of expenditure	Number of cases (who gave details)	Total expenditure (£)	Average expense (£)	Range (£)
In-patient care:				
clothes, toiletries, etc.	101	1,135.85	11.25	0.50 - 55.00
leisure items (books, newspapers, etc.)	157	751.78	4.79	0.26 - 50.00
food/drink	111	593.62	5.35	0.20 - 30.00
other/not stated	21	160.85	7.66	0.50 - 30.00
Total	177*	2,642.10	14.93	0.30 - 66.00
Expenses during out-patients visits	26	78.29	3.01	0.20 - 12.00

* The total number of cases giving details was 177; within this group the number incurring expenditure under different categories was variable

Other Family Costs of Illness

Category of cost	Total cost (£)
Additional expenditure:	
medicines and medical care	4,724.07
communications	4,002.61
hygiene	1,651.11
food and drink	854.67
clothes and bedding	371.93
leisure	466.00
other	5,950.26
Sub-total	18,020.65
Losses due to illness:	
cancelled or postponed arrangements	6,432.17
pre-paid education fees	2,595.88
other	176.00
Sub-total	9,204.05
Expenditure/losses on holiday abroad:	
additional expenses	5,444.78
loss of holiday	49,602.00
Sub-total	55,046.78
Total	£82,271.48

Two thirds (£55,046.78) of the costs were associated with infections acquired abroad and largely represented loss of holiday time.

Additional expenditure

Additional expenditure amounted to £18,020.65. Over a quarter (26%) was to purchase medicines in chemists and private medical care. Altogether 486 cases spent £2,724.02 on medicines purchased for self-treatment (average £5.60; range £0.20-£50.45). A further £2,000.05 was to purchase care, including private medical care (£1,219.00 for three cases) and child care (£688.30 for four cases) facilities, purchase of nursing aids and compensation of carers.

Communications was a major cost (£4,002.61, 22%). Most of this total (£2,469.67) was telephone calls and a further £1,517.58 was for travel other than to a doctor (GP) or hospital visiting. Purchase of hygiene materials was the third main area of expense (£1,651.11). Most of this was for cleaning or disinfection materials (£545.24) and absorbent pads (£838.79). Lesser amounts were spent on food and drink, particularly bottled water and dietary supplements, and replacement of bedding and clothing. Expenditure on leisure items totalled £466, mostly spent on children (eg. £150 on video hire, £101 on games and £50 on model kits).

A number of other items did not fall into these categories. Six patients mentioned additional heating and lighting. Hire of additional or replacement staff was an important item for self-employed cases and in two instances outside caterers were used for functions which would otherwise have been self-catered. The most expensive item was an estimated £2,000 for two funerals. Other items were legal costs (two cases), although it was not known if this was eventually compensated, and putting a dog in kennels. One case cited a wasted honeymoon; one assumes the value was high but no attempt was made to assess this.

Unexpected consequential losses

Items of additional expenditure represented largely predictable consequences of illness. However, many individuals faced a range of unforseen losses resulting from cancelled arrangements. These fell into three main areas: cancelled or postponed arrangements; pre-paid education fees; and interrupted foreign holidays (considered below). Cancelled or postponed arrangements accounted for £6,432.17, £4,820.00

of which was due to cancelled holiday arrangements. The remainder was mainly associated with pre-paid fees, travel passes and theatre tickets. Pre-paid education fees of £2,595.88 included school and playgroup/nursery fees and missed training or course fees. A further £176.00 losses were ascribed to food discarded by one case.

Interrupted foreign holidays

The most significant area of costs (£55,046.78) associated with unforseen expenditure and losses arose from spoilt foreign trips, mostly for holiday purposes. Costs associated with lost holiday time were estimated at £49,602.00, 90% of the costs associated with foreign holidays (Table 4.15). A feature of these costs was days lost by carers (1,323 days), which was double that for cases. A further £5,444.78 losses were associated with cancelled pre-paid arrangements or excursions or with items of unexpected additional expenditure.

Over four fifths (82%) of additional expenditure was related to costs of medical treatment or expenses resulting from curtailed or extended stay. Treatment costs recorded by 157 cases averaged £14.18; nine cases said they incurred costs related to extended or curtailed stay but only three persons specified the costs which ranged from £10 to £1,518.

Other costs totalling £885.16 were for purchase of food and drink (usually bottled water), hygiene materials, clothing, telephone calls and travel. Only 21 cases indicated they were making claims for compensation. Details of the amount and success of claims was not sought. To have done so may have considerably delayed response. Thus, costs to this small group of individuals may have been overestimated.

Summary of costs to families

Costs to families were estimated at between £95,973 and £104,843. Treatment related costs were £13,702 to £22,571 and accounted for 14% to 22% of the total. Other expenditure and losses of £82,271.48 were related either to the purchase of materials and services to reduce the effects of illness or resulted from missed opportunity to use pre-paid activities or services. The single most important item mentioned was losses associated with disrupted holidays abroad which were £55,046.78 accounting for over half (53%-57%) of all family related costs.

Costs of Illness Acquired Abroad (303 Cases)

Category of cost	Total cost (£)
Days of holiday lost*:	
cases - in bed .... (368 days)	10,304.00
at hotel ..... (262 days)	5,502.00
able to go out (859 days)	6,013.00
carers - .... (1,323 days)	27,783.00
Sub-total	49,602.00
Cancelled arrangements/trips	514.75
Additional expenditure:	
medical treatment	2,226.66
curtailed/extended stay	1,818.21
food and drink	159.40
hygiene	15.00
communications	167.20
travel	279.00
clothing	59.56
not stated	205.00
Sub-total	4,930.03
Total	£55,046.78

* based on the average cost of a holiday abroad in 1988/89

Lost productivity

The largest cost component was lost production from sickness related absence from work; estimated at £507,555 (minimum) and £559,401 (maximum) (Table 4.16). Altogether 551 cases took time off paid employment because of illness and 537 detailed 9,337 days off. Most (72%) was time off full-time employment. A further 1,493 days was recorded for 234 cases for whom someone took time off paid employment to care for them. Thus a total of 10,830 days off work were recorded.

The average length of time off paid employment by cases was greater for women (23.2 days) than for men (14.6 days) (Table 4.17). The reasons for this are unclear and to explore the possibility that it may have related to occupation, a more detailed analysis of time off by type of job was made for 534 cases giving details of their work (Table 4.17).

Individuals who did a job in which there was a perceived risk of transmitting their infection were off work the longest. A higher proportion of women (33%) worked in these jobs than did men (11% in this sample). Men in these jobs were away on average over six days longer than women. However, whereas the average length of time off work dropped by half for men in non-risk jobs, it remained unchanged for women in non-risk jobs. The average length of time off was highest in food handlers and in the medical profession, although anomalously doctors were away a far shorter period than other health workers.

Firm conclusions cannot be drawn from this relatively small sample with wide variation and small numbers within categories. Difficulties in detailed coding of jobs may have resulted in missclassification of women employed, eg. as packers, in the retail food industry. However, the results indicated that women and all persons in "at risk" occupations were off work for longer than individuals in "non-risk" jobs.

Summary of costs

The estimated tangible costs were £996,350 to £1,091,131 (Table 4.18). Between £392,822 and £426,887 was related to the public sector and included £157,162 to £191,228 associated with investigation and follow-

Table 4.16

Costs to the Economy from Lost Production**

Employment	Days off work	Minimum earnings (£) Gender-specific*	Maximum earnings (£) Non-gender-specific†
Full-time:			
Men	3,552	174,971.52	155,400.00
Women	3,199	108,030.23	139,956.25
Part-time:			
Men	39	1,921.14	1,706.25
Women	2,547	86,012.19	111,431.25
Total	9,337	370,935.08	408,493.75
Carers:			
Men (full- and part-time)	542	26,698.92	23,712.50
Women	936	31,608.72	40,950.00
Not known	15	656.25	656.25
Total	1,493	58,963.89	65,318.75
Grand total	10,830	429,898.97	473,812.50
Costs including labour (18%)		507,554.98	559,400.82

* Gender-specific (daily) rates: males, £49.26; females, £33.77

† Non-gender specific-rate: £43.75

**The analysis will include days off work for some individuals excluded by LAs because of their occupation and paid compensation. It was not possible to distinguish what proportion of time off for these individuals was due to illness. However, the compensation paid by LAs (£11,495) represents only 2.2% of the minimum estimate for lost production.

Average Number of Days Off Work for Those Employed in "At Risk" Occupations

Occupation	Average number of days off work			
	Males	(n)	Females	(n)
Medical				
doctor	5.5	(2)	3.0	(2)
nurse	48.5	(2)	18.6	(26)
other health professional	-		37.8	(4)
ancillary worker/porter	25.0	(2)	23.3	(12)
Welfare/Teaching				
nursery/playgroup	-		21.5	(5)
schoolteacher	70.0	(1)	21.3	(11)
welfare worker	2.0	(1)	22.8	(5)
Food production				
food factory	25.0	(1)	43.5	(2)
waiter/steward/barman	44.25	(3)	40.3	(8)
cook/chef	23.35	(9)	24.8	(11)
butcher	39.3	(3)	21.0	(1)
baker	4.0	(1)	-	
fishmonger	30.0	(1)	-	
other retailer	10.0	(1)	22.2	(12)
Average: "at risk" occupations	29.9	(27)	23.1	(99)
Average: all other occupations	13.3	(216)	23.8	(192)
Average: all occupations	14.6	(243)	23.2	(291)

"At risk" occupations are defined as any job where there is a perceived risk of transmission of infection, either by contamination of food or by cross-infection spread to vulnerable groups in the population (i.e. the very young, elderly or ill).

(PHLS Salmonella Sub-committee, 1990)

Table 4.18

Summary of Costs

Category of cost	Minimum Total cost (£)	Minimum Cost per case (£)	Maximum Total cost (£)	Maximum Cost per case (£)
Public Sector				
Local authority*	85,632.69	57.79	94,393.11	63.70
Laboratory*	71,529.40	48.27	96,834.40	65.34
	157,162.09	106.06	191,227.51	129.04
General Practice	31,367.50	25.52		
Hospital services	196,601.75	159.97		
Prescribed medicines	7,690.31	6.26		
	235,659.56	191.75	235,659.56	191.75
Sub-total	392,821.65	297.81	426,887.07	320.79
Families and Economy				
Costs of treatment:				
GP	4,666.58	3.80	5,375.65	4.37
hospital	9,035.32	7.35	17,195.63	13.99
Other costs of illness	82,271.48	66.94	82,271.48	66.94
	95,973.38	78.09	104,842.76	85.30
Lost production	507,554.98	412.98	559,400.82	455.17
Sub-total	603,528.36	491.07	664,243.58	540.47
Grand total	996,350.01	788.88	1,091,130.65	861.26

* Evaluated on 1,482 cases; all other costs per case based on 1,229 cases

up of cases. Costs associated with treatment, in particular use of hospital services, accounted for £235,659 of public sector costs. Society-related costs totalled £603,528 to £664,244 of which £507,555 to £559,401 respectively was loss of production resulting from sickness-related absence from work. Costs of illness to individuals and their families were between £95,973 and £104,843.

Costs per case were calculated by dividing local authority and laboratory costs by the relevant sample size, 1,482; costs per case for the remaining categories were based on the total of 1,229 respondents. The cost per case was estimated between £789 and £861, however, the range in costs per case within categories was very wide and very sensitive to hospitalisation costs and lost production. Thus, for cases admitted to hospital, treatment costs ranged from £119 (patient admitted for one day) to £4,046 (patient in hospital for 34 days). Extended hospital stay had a knock-on effect, resulting in corresponding increases in travel costs to family and friends visiting the patient. Similarly, for patients off paid employment the costs of lost production ranged widely, depending on the number of days off.

Intangible Costs

In addition to the costs of illness described, there are intangible costs for which no monetary values are readily available. These include death, pain and suffering (including loss of leisure), schooling and housewives' time. The methods for valuing these areas are not necessarily well developed but the importance of including them is acknowledged by economists. Because of the difficulties in providing firm estimates for these, the approach taken was to provide a range of costs and to compare costs derived from alternative methodologies.

Loss of life

Three people in the sample died with salmonella infection. Applying the average values of life for the four approaches in Table 4.19 gave estimates between £152,700 and £9 million. However, the sample included two people, a child and an elderly person, with pre-existing life-threatening conditions for whom salmonella infection probably contributed little to the eventual outcome. The remaining case was an

Table 4.19

Estimated Value of Lives Lost in Sample

	Method of valuation				
	VL[1]	HC[2]	L & S[3]	WP[4] Lower	WP[4] Upper
Average value of life (£)	50,900	146,000	207,000	551,600	3,000,000
1 case (10%)	5,090	14,600	20,700	55,160	300,000
2 cases (1%)	1,018	2,920	4,140	11,032	60,000
Total	6,108	17,520	24,840	66,192	360,000

[1] value of life
[2] human capital
[3] Landefeld and Seskin
[4] willingness to pay

elderly person whose salmonella infection probably caused death.

Clearly, it would be inappropriate to apply average values to these cases. Yule (1986) assumed a life expectancy of 10% of normal for elderly cases and this was applied to the one elderly case. The two cases with pre-existing terminal conditions presented a more difficult problem because it was impossible to predict how long they would have lived; however, they may have had some life expectancy. To allow for this a value of 1% of normal was assumed. This gave a range of £6,108 to £360,000. A more complex series of calculations were necessary to value lives lost annually where detailed information was not available. The adjusted value of lives lost was calculated for 1988 for each of the main approaches (Table 4.20; Appendix 4g) which gave estimated values between £435,853 and £25,131,000.

Loss of normal activities

Salmonella infection causes varying degrees of discomfort and may limit an individual's ability to take part in leisure activities. Estimates of these effects have been included in studies of salmonella-related costs as either "pain and suffering" or "loss of leisure" (Cohen, 1982; Yule et al, 1986; Roberts et al, 1989; Curtin, 1984). In the sample 1,151 cases indicated that they experienced varying levels of restriction on normal activity (Appendix 4m). The average length of illness was about 18 days and within this, activities were limited by being confined to hospital or to bed at home, confined to home but able to get up, able to go out but feeling ill, and activities unaffected.

Two surrogate measures were used to value loss of normal activities. The first, based on DoT estimates for pain and suffering, when applied to hospitalised (227) and non-hospitalised (1,225) cases gave a value £3,133,876 (227 x £12,613 = £2,863,151) + (1,225 x £221 = £270,725). Because the value of pain and suffering was a notional amount, to allow for the likely wide range of effects within severity groups and to incorporate different value systems the figure was adjusted plus or minus 50%, thereby giving lower and upper estimates for pain and suffering of £1,566,938 and £4,700,814 respectively.

The second measure was based on valuation of leisure time lost (Krug

Table 4.20

Values of Lives Lost from Salmonella Infection : England and Wales, 1988 (58 cases by age group)

Degree of cause of death		Age group (years) 0-4	5-14	15-44	45-59	60-64	≥65	Total
VL:	Caused	28,861	26,800	56,245	43,316	30,438	180,644	366,304
	Contributed	7,215	6,626	8,399	4,836	3,309	33,136	63,521
	Unrelated	147	382	255	255	255	4,734	6,028
	Total	36,223	33,808	64,899	48,407	34,002	218,514	435,853
HC:	Caused	71,540	66,430	161,330	124,246	87,308	518,154	1,029,008
	Contributed	17,885	16,425	24,090	13,870	9,490	95,046	176,806
	Unrelated	365	1,095	730	730	730	13,578	17,228
	Total	89,790	83,950	186,150	138,846	97,528	626,778	1,223,042
L & S:	Caused	101,430	94,185	228,735	176,157	123,786	734,643	1,458,936
	Contributed	25,358	23,288	34,155	19,665	13,455	134,757	250,678
	Unrelated	518	1,553	1,035	1,035	1,035	19,251	24,427
	Total	127,306	119,026	263,925	196,857	138,276	888,651	1,734,041
WP 1:	Caused	270,284	250,978	609,518	469,412	329,857	1,957,628	3,887,677
	Contributed	67,571	62,055	91,014	52,402	35,854	359,092	667,988
	Unrelated	1,379	4,137	2,758	2,758	2,758	51,299	65,089
	Total	339,234	317,170	703,290	524,572	368,469	2,368,019	4,620,754
WP 2:	Caused	1,470,000	1,365,000	3,315,000	2,553,000	1,794,000	10,647,000	21,144,000
	Contributed	367,500	337,500	495,000	285,000	195,000	1,953,000	3,633,000
	Unrelated	7,500	22,500	15,000	15,000	15,000	279,000	354,000
	Total	1,845,000	1,725,000	3,825,000	2,853,000	2,004,000	12,879,000	25,131,000

and Rehm, 1983; Curtin, 1984). Hours of leisure lost were estimated for the study sample at 152,514. The result, shown in Table 4.21, of £374,622, was less than that estimated for pain and suffering.

Loss of schooling

The sample included 139 children of school age; 130 gave details of length of illness (no information, 7; not ill, 2). Ninety-one nursery and primary age children were ill for 1,496 days or 1,069 schooldays (average: 11.7 days), and 39 secondary age pupils were ill for 856 days or 611 schooldays (average: 15.7 days). Applying the daily average capitation allowance for each age group gave estimated costs of £11,623 (£6,187 primary and £5,436 secondary). Some days may have fallen over half-term or Christmas holidays and the costs may be overestimated. To incorporate this assumption the total was adjusted by minus 50%, giving minimum and maximum values of £5,812 and £11,623 respectively.

Loss of housewives' time (Adult women not in full-time paid employment)

The estimated costs resulting from loss of housewives' activity was £74,111 (Table 4.22). This result was adjusted plus or minus 50% to allow for varying degrees of sensitivity of the result to the assumptions made. This gave lower and upper estimates of £37,056 and £111,167 respectively. Assuming the sample to be representative of all reported cases, then the estimated costs for all reported cases would have been 20 times higher: £741,120 to £2,223,340.

Summary of intangible costs

The intangible costs are presented in Table 4.23. Aggregated costs excluded loss of schooling and housewives time on the basis that they were likely to be components of the pain and suffering estimate. The effect of removing them was minimal since they accounted for only 2% to 3% of the sample costs. Thus aggregated costs for the value of lives lost and pain and suffering ranged from £1.57 million to £5.07 million. These totals were very sensitive to the estimated values for pain and suffering which accounted for over 93% of the total.

In extrapolating costs to include all reported cases in 1988, values

Table 4.21

Estimated Value of Lost Leisure Time

Based on Average Hourly Wage Remuneration

Type of case	Number of cases	Number of days ill	Hours of leisure	Cost (£) (average hourly salary)
In hospital				
confined to bed	171	817	8,836	31,923
able to get up	150	636	4,542	24,845
At home*				
confined to bed	665	3,484	24,886	136,126
able to get up	763	8,421	60,150	164,510
able to go out	418	4,407	31,478	17,218
activities not restricted	286	3,167	22,622	-
Total	1,151†	20,932	152,514	374,622

* includes individuals not allowed back to work post recovery, because of their type of employment

† all cases for whom information was given; each case may appear in more than one category in this column

Details of illness were not specified for 78 cases (250 days of illness)

Table 4.22

Loss of Activity of Adult Women (excluding students)

	Not in paid employment			Total	Employed		Total
	Housewife	Retired	Unemployed		Full-time	Part-time	
Number in sample	95	39	12	146	202	146	494
Admitted to hospital	20	7	4	31	21	19	71
Number of days:							
in hospital or confined to bed at home	455	210	85	750	784	670	2,204
at home but able to get up	787	269	56	1,112	2,914	1,762	5,788
infected but not restricted	112	66	26	204	745	509	1,458
Total	1,354	545	167	2,066	4,443	2,941	9,450
Total days restricted activity	1,242	479	141	1,862	3,698	2,432	7,992

Calculation of estimated costs from loss of housewives' activity:

in hospital or confined to bed (100% loss):	not in paid employment	= 750	days at £33.77	= £25,328
:	part-time workers	= 670/2	days at £33.77	= £11,319
at home but not confined to bed (50% loss):	not in paid employment	= 1,112	days at £16.89	= £18,782
:	part-time workers	= 1,762/2	days at £16.89	= £14,880
full-time workers . . . . (5% loss):	in hospital	= 784	days at £1.69	= £ 1,325
:	at home	= 2,914	days at £0.85	= £ 2,477
			Total	£74,111

Table 4.23

Estimated Intangible Costs

Category of cost	Study sample (£)		All reported cases 1988* (£)	
	Minimum	Maximum	Minimum	Maximum
Loss of life	6,108	360,000	435,853	25,131,000
Pain and suffering	1,566,938	4,700,814	31,338,760	94,016,280
Total	1,573,046	5,060,814	31,774,613	119,147,280
Loss of schooling	5,812	11,623	116,240	232,640
Housewives' time	37,056	111,167	741,120	2,223,340

* approximately 23,000

attributed to loss of life were based on the actual numbers of recorded deaths. All other values were calculated by multiplying the sample estimates by 20. This was on the two assumptions that the sample was a reasonable reflection of reported cases and was about 5% of the total. Again aggregated costs were for value of lives lost and pain and suffering and estimated intangible costs were between £31.77 million and £119.15 million (Table 4.23). These values were particularly sensitive to values for pain and suffering. However, this was less so for the maximum estimate where the value attributed to lives lost was 21% of the total compared with 1% of the minimum value. The estimates attributed to lives lost were very sensitive to the method of evaluation. Overall low costs were a function of the age distribution, which was heavily skewed towards the elderly, and to the high proportion of cases with pre-existing serious conditions.

Estimate of the National Costs of Human Salmonella Infection in England and Wales in 1988

There is little information about either the incidence of salmonellosis in England and Wales or the range of severity of illness. Therefore, to estimate the national burden of disease it was necessary to make inferences about these elements based on the data that was available.

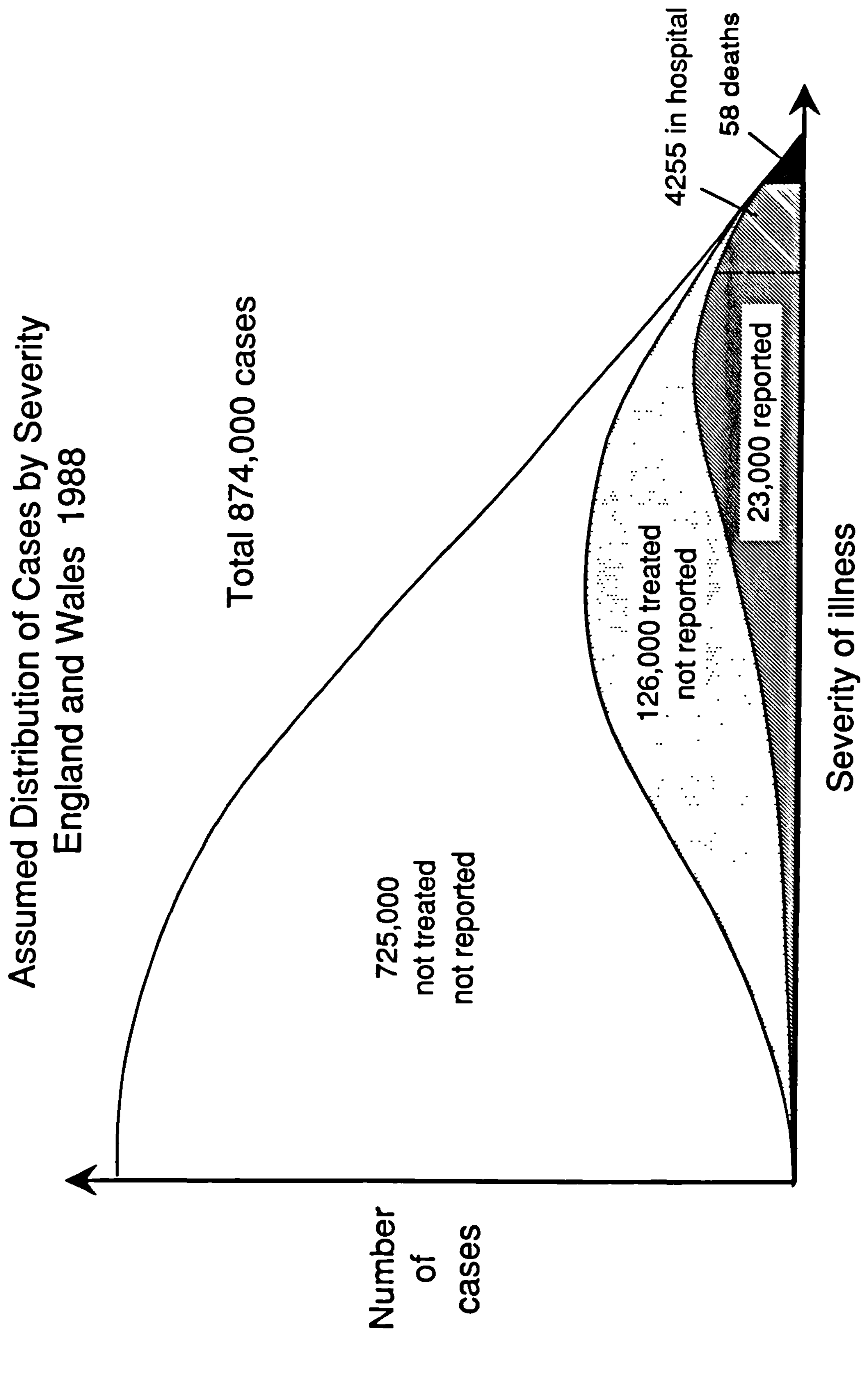
Numbers of cases

The most recently available estimate of numbers of cases of gastroenteric illness in the community was derived from a survey of a randomly selected sample of adults in 1988 (MAFF, 1988). Applying these multiplication factors to the approximately 23,000 reported salmonella cases in 1988 suggested about 874,000 people were affected, including 149,000 who sought medical treatment (Figure 4.1). This would include 4,255 (18.5%) cases admitted to hospital.

Severity of illness

To estimate total national costs two approaches were taken. Both incorporated a scale of costs per case to reflect severity of illness. It was assumed that reported cases probably represented the severe end

Figure 4.1



Assumed Distribution of Cases by Severity
England and Wales 1988
Total 874,000 cases
725,000
not treated
not reported
126,000 treated
not reported
23,000 reported
4255 in hospital
58 deaths
Number
of
cases
Severity of illness

of the spectrum of illness, that unreported but treated cases depicted a mid-range, and that unascertained cases were mostly only mildly affected. It was also recognised that each category represented a wide distribution of severity and that the more severe the case the greater the likelihood of the person being sampled and reported. These assumptions are portrayed in Figure 4.1 which seeks to present the likely distribution of cases in 1988 by level of severity. The costs derived from these two approaches are detailed below.

Approach I

The first approach assumed that severity was reflected in the level of medical attention demanded. This showed a decline in average length of illness and time off work corresponding with a decline in the level of service demanded. Thus, average length of illness was 22 days for hospitalised cases, 19.6 days for cases visited at home by their GP, 16.7 days for those having surgery consultations and 14.2 days for untreated cases. Cases in these categories showed a similar decline in numbers of days off work of 9.9, 7.9, 7.3 and 4.3 days respectively. Tangible costs, applied by category, showed a decline in absolute and average costs with the level of treatment demanded (see Appendix 4n.i). Thus 40% of the total was ascribed to hospitalised cases, 28% each to cases visited at home or making surgery visits, and 4% to those not using medical services. The costs for those who visited their doctor's surgery was elevated by large family-related losses and investigation costs. However, average costs declined across all groups.

To estimate the national tangible costs for 1988, average costs for each category derived from Appendix 4n.i were used. Costs for all reported cases of over £18.5 million were based on the assumption that the use of medical services in all reported cases was the same as in the sample (Table 4.24). To estimate costs for treated but unreported cases (£101.68 million), average costs of illness were used to reflect the likely range of severity of illness. To estimate costs associated with untreated and unreported cases (£210.98 million), average costs for cases not receiving treatment were used but public sector costs were removed on the basis that these cases neither received medical treatment nor were they investigated. Production losses may be overestimated because of the inclusion of symptomless cases being excluded from work in the "no consultation" group. If average

Table 4.24

Estimated Costs* : All Cases of Salmonellosis in England and Wales, 1988

***Approach I* : Type of Treatment Demanded**

Type of case	Estimated cases	Public sector costs (treatment costs) (£)	Family costs (£)	Lost production (£)	Total costs (£)
Reported:					
in hospital	4,255	4,314,570 (3,863,540)	812,705	2,323,230	7,450,505
visited by GP	7,889	1,341,130 (504,896)	694,232	3,187,156	5,222,518
visited surgery	9,200	1,297,200 (322,000)	745,200	3,155,600	5,198,000
no consultation	1,656	203,688 (28,152)	112,608	369,288	685,584
Total	23,000	7,156,588 (4,718,588)	2,364,745	9,035,274	18,556,607
Treated but unreported	126,000	39,186,000 (25,830,000)	12,978,000	49,518,000	101,682,000
Untreated and unreported	725,000		49,300,000	161,675,000	210,975,000
Total	874,000	46,342,588 (30,548,588)	64,642,745	220,228,274	331,213,607

* at 1988 prices

production loss for this group was halved to allow for this, the total reduced by £82 million (25%). Thus the total was sensitive to estimates for lost production.

Total tangible costs of £331.2 million were estimated for 1988 under Approach I. The largest proportion of these costs was due to lost productivity (67%). Family-related losses accounted for a further 20% of the total. Public sector costs, although the smallest proportion (14%), were nevertheless a significant burden on the taxpayer's purse.

Approach II

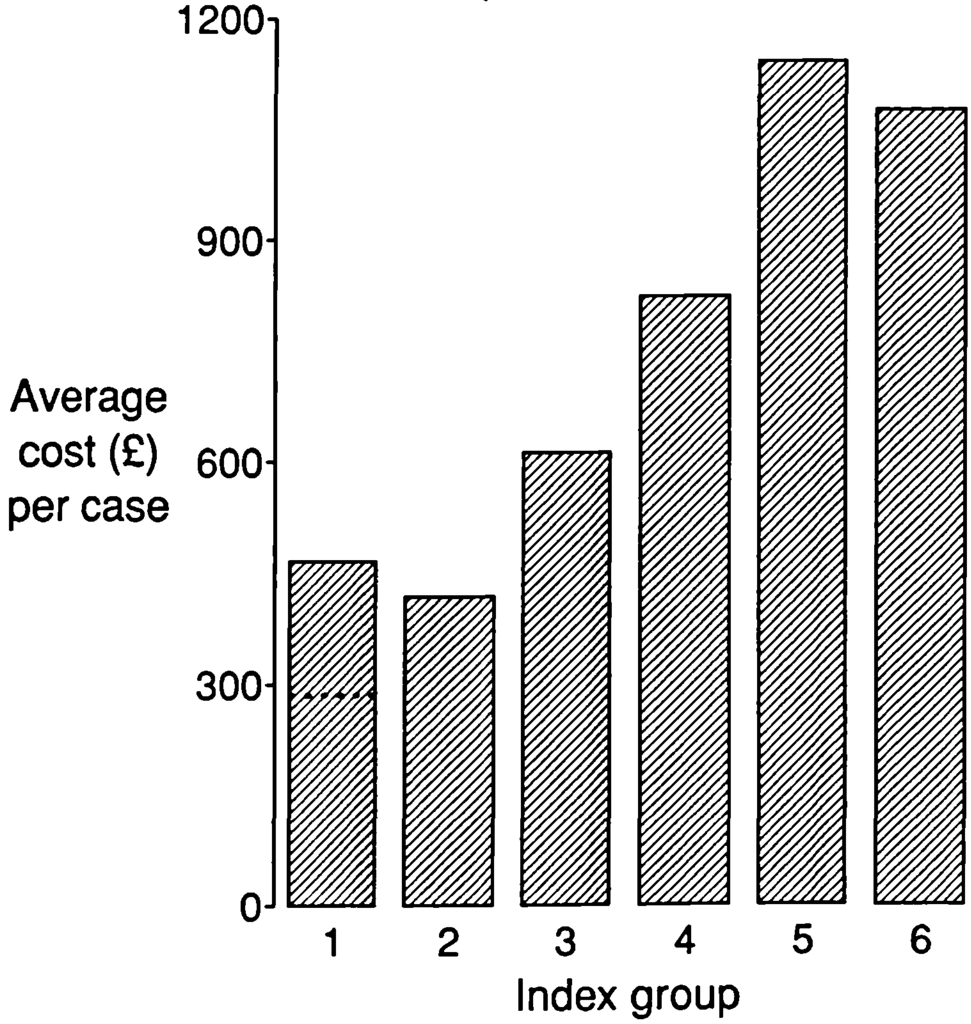
The second approach ranked severity of illness in an index of six groups according to patients' subjective assessment of how severe each symptom was and the number of symptoms experienced. This showed a progression of increased length of illness, time off work or use of medical services with increase in severity of illness. This was confirmed by a high positive correlation between severity index and use of services or time off work (Appendix 4h). Some anomalies occurred; thus the average number of days off work was greater in index group 1 than groups 2 or 3, but did not affect the progressions observed for all other categories. This was because a number of symptomless individuals who were excluded from work were included in index group 1. Since these cases made no demand on medical services they did not affect the progression in the remaining categories. In some categories, i.e. length of illness, days off work and use of medical services, average values were lower in group 6 than in group 5. However, the differences in values between these two groups were relatively slight and may indicate no effective, measurable difference in severity, suggesting they should be combined.

Total and average tangible costs associated with cases increased with severity (Figure 4.2; Appendix 4n.ii). High average costs in group 1 compared with group 2 were due to production loss by symptomless cases excluded from work. Removal of these cases reduced the average costs of lost production by more than 50% to £143, but had little effect on the remaining categories. This also reduced overall average costs to £285 per case, more than £100 less than the average costs in group 2 (Figure 4.2). Low costs in group 6 resulted from lower average family-related "other" costs and lower average costs for lost production.

Figure 4.2

Average Cost per Case for Severity Index Groups

(···· symptomless excreters removed)



Cases in group 6 had a slightly lower average length of illness and time off work than patients in group 5. One possible explanation would have been a higher proportion of non-working cases in this group; however, analysis of the age profile showed almost no difference in the proportion of patients aged under 16 or >65 years when compared with the other index groups.

Costs of reported cases were £18.55 million (Table 4.25), treated and unreported cases £101.68 million and untreated and unreported cases £110.93 million. The tangible costs for 1988, calculated by this approach were £231.2 million. As with *Approach I,* production loss accounted for the highest proportion (70%) of this and the overall total was sensitive to assumptions made in estimating these costs. Thus if costs of lost production were halved, the total costs would be reduced by more than a third. Public sector costs were similar for both approaches but accounted for a higher proportion (20%) of the lower total in *Approach II* and were double the family-related costs.

Summary of total national costs of salmonellosis in 1988

The estimates indicated that the total tangible costs of human salmonella infection in 1988 were between £231 million and £331 million. In addition, intangible costs were estimated to be at least between £32 million and £119 million. Thus the burden of salmonella infection lay between £263 million and £450 million for 1988.

Table 4.25

Estimated Costs* : All Cases of Salmonellosis in England and Wales, 1988

***Approach II* : Index of Severity of Illness**

Type of case	Estimated cases	Public sector costs (treatment costs) (£)		Family costs (£)	Lost production (£)	Total costs (£)
Reported:						
Index group - 1	354	47,082	(9,558)	3,540	115,050	165,672
2	1,964	406,548	(198,364)	64,812	353,520	824,880
3	5,428	1,297,292	(721,924)	434,240	1,590,404	3,321,936
4	9,527	2,867,627	(1,857,765)	962,227	4,010,867	7,840,721
5	3,588	1,521,312	(1,140,984)	620,724	1,948,284	4,090,320
6	2,139	1,009,608	(782,874)	278,070	1,016,025	2,303,703
Total	23,000	7,149,469	(4,711,469)	2,363,613	9,034,150	18,547,232
Treated but unreported	126,000	39,186,000	(25,830,000)	12,978,000	49,518,000	101,682,000
Untreated and unreported	725,000			7,250,000	103,675,000	110,925,000
Total	874,000	46,335,469	(30,541,469)	22,591,613	162,227,150	231,154,232

* at 1988 prices

DISCUSSION

This thesis presents the results of the first reported national study into the economic and social effects of human salmonella infection in England and Wales. Public sector and society costs, and intangible costs were estimated at between £263 million and £450 million in 1988.

A person-based methodology was adopted to identify and quantify infection-related tangible costs. The costs of illness included direct costs of investigation and treatment of cases, as well as costs to the affected person and his or her family and lost production from sickness related absence from work. Only this last category directly affects the economy in that it represented a potential loss to the GNP.

Information on costs was obtained via a questionnaire completed by the affected person and the investigating EHO. This was to minimise reliance on expert opinion or costing data based on small, single outbreak, and possibly unrepresentative samples. Although this approach was likely to underestimate costs, eg. where insufficient prompting would lead to under-recording of costs to individuals, the results would give a realistic minimum cost-of-illness.

The population from which the sample was drawn represented just over half the population of England and Wales. The sample varied in some respects from the national population; there were differences in regional and, social class distribution and ethnicity. The sample also showed an excess of children aged under 5 years when compared with the population of England and Wales. This may have indicated either increased susceptibility, or a greater likelihood for doctors to submit a specimen for faecal testing when the patient is a young child. Thus, in any extrapolations made from the study sample to the population as a whole this should be borne in mind. However, the sample approximated closely to nationally reported salmonellosis with respect to serotype identified and the age distribution of cases.

The study was unique in its detailed analysis of the costs of salmonellosis to affected individuals and in its attempt to relate demand for treatment and costs of salmonella infection to the severity of the illness experienced by individuals. The latter was of particular importance where extrapolation to national costs of all, including unreported, cases was attempted. To have based such extrapolations on the average costs of reported illness only would clearly have been inappropriate since many of those who were unreported were likely to have been only mildly affected. The resulting costs would be a gross overestimation and possibly viewed as unrealistic. The inclusion of intangible cost estimates, such as the value of lives lost, indicated that these made a substantial contribution to the overall costs-of-illness estimates. Indeed, Roberts (1991) commented that where these costs have been included in studies they have been the most significant cost category identified for salmonellosis as well as other gastrointestinal infections.

This discussion is divided into two parts. The results of the costing survey are considered first and then, second, the estimated annual, national costs of salmonella infection are discussed.

Results of the costing survey

The survey identified tangible costs of about £1 million associated with the cases in the study sample (Table 4.18). Public Sector costs accounted for 39% of the total, just under half of which was for the investigation of cases. Costs to families and the economy accounted for the remaining 61%. These included production losses associated with sickness-related absence from work which dominated society costs and were over half of the total costs identified. Although relatively small, the study showed that acute salmonellosis may be costly to cases and their families and that seeking medical care is not without cost.

Public Sector costs

Public Sector costs fell into two main areas: investigation and treatment (Table 4.18). As might be expected the study showed that most local authority costs were connected with the follow-up of cases and included staff time and travel (Table 4.6). It could be argued that this is what EHOs are employed to do anyway. However, EHOs are busy people with a wide range of responsibilities including pollution control, housing, grant applications, etc. and could be fully employed in these activities. Investigation of salmonella infections may displace these other activities and thus represent an opportunity cost. It could also be argued that EHO time could be better spent on preventive activities such as hygiene education for food handlers and routine inspection of production premises. Indeed, at least one study in the USA indicated that the costs of preventive activities, including regular catering staff training and inspection of premises, was far lower than the costs of an outbreak, although this was not a cost-benefit study (Levy and McIntire, 1974). They calculated that training courses for food handlers cost $5 per person and inspection of premises about $11 per visit (1974 prices). The costs of these activities, which were considered to be effective in reducing the chance of an outbreak occurring, compared favourably with the costs of the outbreak ($28,733) as a whole and to the restaurant owner in particular ($5,000).

A significant amount of local authority investigation costs, (£11,494), was compensation paid to 39 persons excluded from work (Table 4.6). This would normally include persons working in an occupation where they might be at risk of transmitting the disease to others. The average compensation paid was £295. Since an infected person in one of these jobs could potentially cause many cases, at an average cost of £789 per case, this precaution should be viewed as both sensible and possibly cost-effective. The number of cases infected each year by this mechanism is unknown and probably small, suggesting that a more detailed analysis is indicated. Joseph and Palmer (1989) found that only two outbreaks in a review of 248 salmonella outbreaks in hospitals, a particularly vulnerable population, between 1978 and 1987, were likely to have been due directly to infected food handlers.

Altogether 6,614 specimens were submitted for laboratory investigations at a cost of between £71,529 and £96,834 (Table 4.8), accounting for approximately half of the total investigation costs (Table 4.18). Since many of those affected did not fall into any of the "at risk" categories described by the PHLS Salmonella Sub-committee (1990), the necessity for so many specimens to have been tested is questioned and may provide an area where costs could be reduced (see Chapter 5).

Most of the Public Sector costs (55% - 60%) were associated with the treatment of cases. These costs were particularly sensitive to the costs of hospital based care which totalled over £196,000, including

£173,000 for in-patient treatment (Tables 4.9, 18). The average treatment cost per case for patients admitted to hospital was £762, three times the average overall health-care cost for all cases.

The average cost for admitted cases was similar to the upper range of in-patient treatment costs identified in outbreaks in Scotland (Yule et al, 1988b), and in England and Wales (Roberts et al, 1989), and in a study of health-care costs of salmonellosis in 1986 (Sockett and Stanwell-Smith, 1986). Slightly higher costs for hospitalised cases were recorded for studies in North America (Curtin, 1984; Todd, 1985ab; Roberts, 1991). This probably reflected higher treatment costs in the USA and Canada and it would be interesting to make a detailed comparison based on costs of treatment but taking into consideration management practices. For example, length of stay in hospital in Canada recorded in the study by Curtin (1984) indicated the average increased with age, as in this study, but was longer in every age group in Canada; in particular, length of stay in Canada was almost double that recorded in England and Wales for young children and the elderly.

Almost one fifth of patients in the sample were admitted to hospital. This proportion was consistent with two previous studies in England and Wales (Roberts et al, 1989; Cowden et al, 1989c) and one in Canada (Curtin, 1984). As might be expected the majority of in-patients were seen in A & E department prior to admission. The study indicated that young children were more likely to be admitted than those aged over 10 years and that cases not admitted on the first visit were more likely to make further visits to the A & E department. Half of the patients in this latter group were subsequently admitted to hospital.

Referral for hospital out-patient treatment was not necessarily related to previous in-patient care. Thus, although over half of out-patients had previously been admitted, this group (53 cases) accounted for less than a quarter (23%) of cases who received in-patient care. Multiple out-patient visits were also less likely in previously admitted patients (38% of cases) than in those who had not been admitted to hospital (50% of cases). Two patients made as many as 10 and 15 visits in total over a period of months. The reasons for the multiple out-patient visits are not known and may warrant further investigation. They may reflect follow-up of cases with persistent excretion of salmonellas, or the occurrence of longer-term sequelae.

Long-term sequelae of gastrointestinal infection, including reactive arthritis, malabsorption problems and renal failure, have been recorded. The incidence of many of these conditions is not known, although in a recent review paper Maki-Ikola and Granfors (1992) presented evidence that between 1.2% and 7.3% of individuals with salmonella infection develop reactive arthritis. The long-term and potentially severe nature of such sequelae suggests the costs to the Public Sector and society, including the affected individual, are likely to be high. There is evidence that the risk of developing such sequelae may be to some extent predictable in that they are more likely to occur in particular "risk" groups. Thus, individuals with sickle-cell disease are more prone to developing salmonella osteomyelitis (Diggs, 1967; Molyneux and French, 1982). Where such individuals can be recognised, case management practices may reduce the risk.

Under half (42%) of the patients admitted to hospital travelled by ambulance, although this group accounted for almost all recorded journeys by ambulance (Table 4.9). In most instances cases travelled to, as well as from, hospital by private car. Use of ambulance services accounted for only one per cent of the costs of health care.

Although only 13% of the costs of health care, demand for GP consultations was the next largest area of cost. Because of the way in which GPs are paid for their services in the UK it could be argued that there is no opportunity cost associated with a GP consultation. However, in this study the view was taken that GPs are normally fully employed, busy people and that the time taken up by an additional patient who has salmonellosis precludes the doctor from doing something else almost as valuable. That is, the opportunity cost is not zero. This follows the approach taken by Cohen (1982), Yule et al (1986) and Roberts et al (1989), although the method of calculating the cost of GP consultations adopted by Cohen and Yule differed.

Cohen and Yule estimated consultation costs by dividing total expenditure on GPs by the number of consultations and adding an estimated amount for prescribed medicines, based on assumptions about the number and type of drug prescribed. In this study the numbers of prescribed drugs was known and these were costed separately. Consultation costs differentiated between home and surgery visits and were based on average GP remuneration after removal of certain fees for extra services, but did not include any capital costs.

Most patients with salmonellosis are unlikely to require support from social or community services because illness is acute and mostly of short duration. An exception might be areas where visits by nurses are more common. Cohen (1982) found high use of nurses in a rural area in Scotland, but a study in Birmingham in 1986 found no such use (Sockett and Stanwell-Smith, 1986). Details of the use of these services were not sought for this sample.

Costs to the NHS of prescribed medicines were calculated at £7,690, 3% of total health care costs. About half the cases received, on average, more than two prescribed medicines. It was not clear to what extent this reflected patient needs or the expectations of doctor and patient about the care required. The type of drug prescribed was not known and may well have been limited to medicines to curtail diarrhoea and vomiting and provide rehydration. In a study of the treatment of hospitalised cases these medicines accounted for most items given to patients with salmonella infection (PN Sockett, unpublished data).

The age and social grouping of cases had no significant effect on demand for services. However, males and females aged 10 to 14 years had the highest average length of illness and showed a relatively high demand for some treatment services. The reasons for these findings are not clear and may relate to the likelihood of a first exposure to salmonella infection occurring in this age group. Some animal models indicate changes in hormone levels may affect immunological responses resulting in greater susceptibility to infection, and this age group would be likely to be affected by alteration of hormone levels (Healing and Nowell, 1985). Further examination of this finding is indicated.

Costs to families and society

Total costs incurred by cases and their families as a result of salmonella infection were about 10% of the total costs of illness for this sample. Detailed examination of the costs of illness to the individual has been a neglected feature of previous studies of the costs of foodborne disease and salmonellosis, largely because estimates have been based on aggregated costs for all cases rather than on a survey of affected individuals.

These costs are better recognised where long-term disability is an outcome and may result in modification of the patient's home, changes in the carer's employment and long-term dietary modification (Hagard et al, 1976). The importance of these costs in the sphere of infectious diseases was hinted at by Dublin and Whitney (1920) for tuberculosis, and identified more specifically by Hastings et al (1987), who examined the costs of measles and by Roberts and Frenkel (1990) in a study of costs of congenital toxoplasmosis. However, none of these studies reported the level of detail itemised by this survey.

It could be argued that individuals actually save money when ill because they do not spend on, for example, food. Curtin (1984), suggested that this may only represent a deferment of expenditure, but this study suggested a transfer of expenditure to dietary supplements and leisure items, thereby providing some sort of compensation for illness. Since this expenditure is directed towards goods the individual would not have otherwise purchased, at least at that time, it represented a true opportunity cost.

It was not assumed that these costs represented the value patients would place on avoiding illness but they do represent some minimum value of benefits. It could also be argued that details of costs and a profile of the physical impact of the illness should be provided as background information in studies which attempt to ascertain benefits using the willingness-to-pay (WP) approach. Some of the costs identified fell directly upon those infected and other costs fell on family members and friends. Costs to families fell into two main areas: those related to treatment and those associated with other losses.

Treatment

Treatment-related costs accounted for 14% to 22% of total family costs (Table 4.18); between 70% and 84% of hospital costs was travelling costs of cases or relatives and friends making visits or accompanying cases to hospital (Table 4.12). Private cars were by far the most important mode of transport, particularly in travelling to or from the doctor's surgery. There were similar proportions of journeys by public transport or cab/taxi for both surgery and hospital visits, although calculation of hospital visits was dominated by journeys made by visitors. These journeys not only represented an opportunity cost in terms of actual expenditure, but also represented an alternative use of time which cannot be directly assessed and possibly represented, for example, a loss of leisure time experienced by such visitors. This begs the question of whether or not some "pain and suffering" allowance should also be included for these individuals. Certainly the calculated travel costs represented a minimum cost.

Patient contributions to prescribed medicines (£2,735) was an important cost to cases. The proportion exempt from charges in the sample was less than that expected for the population as a whole, who contributed to about 20% of items prescribed (The Association of the British Pharmaceutical Industry, 1985). This may be explained by the age structure and composition of the sample, which was largely composed of otherwise healthy people under 65 years of age.

Those admitted to hospital spent £2,642 on a variety of items (Table 4.13). Some of these expenses, which individuals incur in order to present themselves appropriately in encounters with the health sector, have been described by Abel-Smith as the "trousseau effect" (B Abel-Smith, personal communication). In addition to such items, which included night clothes and toilet articles, expenditure on leisure items and dietary supplements was also recorded.

"Other" identified costs of illness totalled over £82,000 (Table 4.14). These included expenditure on medicines bought over the counter, medical care and cleaning and disinfecting agents, as well as clothing and bedding. These were predictable consequences of illness; however, individuals also faced a range of unpredictable costs. Unforseen expenditure and losses resulting from cancelled arrangements included a large proportion of costs arising from spoilt holidays.

Two thirds of non-treatment related costs were associated with illness after holidays abroad (Table 4.14). The main costs came from loss of holiday by the case and by others in his or her party who acted as voluntary carers. Since the number of carer days lost was greater than those of cases it seems likely that, where people travelled in groups, some or all of the group were either involved in care or voluntarily limited their activities to stay with the case. Since 20% of the sample became infected abroad but were also treated on return to the UK, this category represented a considerable slice of the total illness-related costs identified. The study also indicated that some destinations carried a greater associated risk of contracting infection than others (Chapter 3); this could be reflected in weighted insurance costs, much the same as occurs with car insurance and geographical location, which would also cover treatment once back in the UK.

Some losses, whilst obviously of great importance to the individual concerned, defied attempts to apportion a monetary value and the amounts given under both additional expenditure and unexpected losses represented minimum costs to the individual. It was possible that some compensation, via insurance, was sought although average expenditure (most cases spent in the range £67 - £85) was relatively low and would not necessarily result in a claim being made. Apart from over-the-counter medicines and telephone expenses, no prompting was given as to the type of loss incurred, therefore the costs described represented those particularly significant for the individuals concerned. Greater prompting about types of cost may have resulted in recording higher losses, particularly where these related to predictable or likely recurring items such as cleaning materials and pre-paid travel passes.

The largest single cost was lost production. This accounted for 84% of costs to the family and the economy and 51% of overall tangible costs. Most published studies of outbreaks indicate similar results for production losses, although estimates based on single outbreaks have given higher totals. For example, Yule et al (1986) found that productive output loss accounted for almost 70% of tangible costs of an outbreak. However, the outbreak affected predominantly adults, of which half were medical staff. Thus the production loss figures reflected both the high proportion of working adults in the sample and the "high risk" occupations. This would act to inflate the overall costs of the outbreak and therefore the average cost per case. This indicates one of the difficulties which arise when extrapolating, to national costs, from the results of a single outbreak.

The extent to which absence from work affected productivity is unclear and it could be argued that, in some instances, the work will be made up by "slack" in the system or by imposing extra work on other staff. Conversely, absence of a key person may cause loss disproportionate to their apparent contribution. It was impossible to ascertain, in this study, the precise effects on productivity and the method chosen seemed the least biased approximation to productivity loss and an established approach in cost of illness studies (Cooper and Rice, 1976). It could be argued that there is no loss of productivity where absent staff can be replaced from the pool of unemployed. One could also argue, however, that unemployment is a matter for the macro management of the economy and evaluation of health provision should not be unduly affected by the ebbs and flows of cyclical unemployment. For salmonella infection presence or absence of unemployment is largely irrelevant as absence, in most cases, will be relatively short and the costs of temporary replacement of staff would be prohibitive. An exception would be areas of the food industry and other "at risk" occupations where absence may be prolonged until the individual is no longer excreting salmonellas. Where colleagues can cover for an absent individual, productivity loss may be minimised in terms of lost productivity but one might also consider the additional effort imposed on the remaining staff.

About a third of the cases in the sample were away from work for more than 17 days on average. Not all of this was necessarily because the individuals concerned were symptomatic, but there was evidence to suggest that some cases, mainly women, working in "at risk" occupations were away the longest. The exception to this was doctors, whose average length of absence was much less than for other health workers (Table 4.17). This may have reflected pressure on doctors to return to work, and may imply an increased risk of passing infection to their patients if they return to work whilst still having symptoms.

The effect of illness on the family of the case was illustrated by the proportion, 19% of those giving details, of cases for whom one or more people, usually relatives, took time off work in a carer capacity. This was an average of six days for carers in paid employment.

Cooper and Rice (1976) suggested that when loss of income is used as a measure of production loss, then separate consideration of revenue losses by the government from income tax not paid by cases off work, or social security payments to cases could lead to double counting. Thus, these items were omitted from this study. For many cases illness was relatively short and wages or salary, including tax and other statutory contributions, would have continued to be paid by the employer.

Costs of illness for the study sample

The costs estimated in this study suggested that human salmonella infection is expensive to the public sector, families and the economy. Using average costs, the costs to the public sector in 1988 for the 23,000 reported cases would have been between £6.8 million and £7.4 million, and costs to the economy from lost production would have been £9.5 million to £10.5 million with further costs to families of £1.8 million to £2.0 million. However, these are underestimates of the true costs since they take no account of unreported cases, or estimates of intangible costs or of the long-term sequelae of illness, or productivity losses resulting from decreased efficiency in individuals who worked whilst unwell. Thus the costs identified in the survey represented the minimum impact of salmonella infection on cases and their families. The intangible costs of illness estimated for the study sample ranged from £1.6 million to £5.1 million (Table 4.23), thereby increasing the estimated overall costs of illness of the sample to between £2.6 million and £6.1 million.

Costs of illness for all reported cases

Extrapolation of the estimates to include all reported cases in 1988 increased the totals to between £50 million and £139 million (These totals included maximum and minimum estimates of public sector and society costs given above, and intangible costs of £31.8 million to £119.1 million). These extrapolations were sensitive to the size of the intangible costs and therefore to the methods by which they were derived. The components of these costs and the methods by which they were derived for this study are considered below.

Intangible costs of illness fall into two main areas. The first area, mortality costs, related to the valuation of loss of life (Chapter 2). Although the methodology for valuing life may be contentious and not necessarily well developed, the importance of including estimates is acknowledged by economists and forms part of the established framework for decision making in the public sector.

The second area, relating to morbidity, describes the time-costs of illness including loss of housewives' time, schooling and leisure, the latter possibly being included under the general heading of "pain and suffering". Some tangible costs, for example absence from work, may also be described as a morbidity cost (Cooper and Rice; 1976).

The approach to valuation of life adopted in this study was to compare values of life derived by four methods (Chapter 2). The range of values obtained was wide (Table 4.20), however, the estimated values of lives lost from salmonellosis in England and Wales in 1988 by the HC, L&S and the lower WP estimates were relatively close (£1.2 million - £4.6 million). The estimates were lower than those based on the method adopted by Cohen (1982) or those based on a simple extrapolation of average values multiplied by the number of deaths and adjusted plus or minus 50%, as used previously by Roberts et al (1989). However, it was felt that the aggregated estimated values did reflect both the age structure and degree of causality in the groups affected.

In this study morbidity losses were taken to include the limitations imposed on housepersons to carry out their normal activities and non-attendance at school, as well as less definable effects resulting from illness. Salmonellosis can be very unpleasant and results in varying degrees of discomfort, limitation on normal activities and ability to benefit from such things as leisure pursuits. No attempt was made to obtain estimates from individuals which would have reflected the subjective value they may place on avoiding salmonellosis. To have done so would have required an extensive and different type of study. However, to ignore them would under-value the cost of illness and therefore surrogate measures were used to assess these effects. Lower and upper estimates for "pain and suffering" of £1.6 million and £4.7 million were obtained using pain and suffering estimates used by the DoT to assess the effects of road casualties (Table 4.23). These contained a notional allowance for "pain and suffering" in addition to other costs which were removed to avoid double counting. The values used by the DoT have been criticised, both because they are notional and because they are based on a human capital approach which takes no account of the individual's willingness to pay to avoid such risks.

The composition of this notional amount is unclear and for this study is assumed to cover the psychic effect of illness. However, the pain and suffering costs prepared by the DoT were originally based on social security benefit payments for illness, and to that extent measured the value society puts on maintaining an individual who is unable to work normally and may therefore more rightly reflect society's valuation of their productivity, in which case inclusion leads to double counting. Nonetheless, initial results of a revision of these estimates by the DoT, using a WP approach, suggest that the figures used here were too low and should therefore be viewed as a minimum (K McMahon, DoT; personal communication). A lower assessment was derived from an alternative approach which was to put a value on loss of leisure which valued leisure at the same rate as average hourly wage remuneration (Krug and Rehm, 1983; Cohen, 1984).

It could be argued that many and varied activities are actually involved in purchasing leisure; these would include both the amount spent directly on leisure activities, such as sports equipment and theatre tickets, and money spent indirectly on, for example, labour-saving devices, in order to purchase more time for leisure. Thus a more realistic evaluation of leisure time should aggregate these separate components. Even so, the result is likely to underestimate the pain and suffering element since it will tend to reflect only what individuals could afford to spend on leisure time but would not necessarily indicate what they would be willing to pay to avoid the discomfort caused by salmonellosis or any loss of utility from activities pursued whilst the individual was still unwell. It may therefore be more correct if considered a component of pain and suffering rather than a reflection of the true costs.

None of the major studies of the costs of salmonellosis have attempted to put a value on school time missed by children suffering from the illness, yet these appear to be an important component group of those affected by salmonella infection. However, the effects on this group may be even greater from childhood diseases such as measles and chickenpox. For example, White and Axnick (1975) recognised an estimated average 8.7 million schooldays lost each year in the USA due to measles alone. Nonetheless, 2,352 days of schooling lost was estimated for 130 of the 139 children in the sample who recorded time absent from school, an average of 18 days per child. This time represents losses attributable to the daily education allowance which could be viewed as an investment in childrens education, and therefore represents some minimum value of a days teaching.

Loss of housewives' services is a well recognised morbidity cost, although the methods of valuation may be contentious (Cooper and Rice; 1976). Curtin (1984), in assessing costs of salmonellosis in Canada, included housewives' time in his estimations of lost productive output, where it accounted for almost 12% of the total. However, since the output of housewives does not contribute directly to the GNP of the economy, it has been treated separately in this study as a social cost. In an earlier paper on the cost of illness, Rice (1966) valued housewives' time as equivalent to the cost of employing a domestic servant for the same time. This approach, however, under-values a housewife's time, largely by failing to incorporate the many and varied duties that she performs.

An alternative approach assumed that a housewife's work should be valued at least as much as that person could earn in the market, or the market value of the various duties performed should be costed separately, and then aggregated (Cooper and Rice, 1976). This latter approach would provide a more accurate assessment of the use and value of a housewife's time but was outside the scope of this study. For this study, housewives' time has been valued at the average hourly remuneration rate for women in paid employment. This was felt to incorporate a reasonable reflection of the average value of all the duties a housewife executes and was closest to the approach advocated by Cooper and Rice. The calculations were adjusted to reflect the degree of limitation on activities, and to include a notional amount for missed housework which would have been carried out in the evenings and at weekends by women otherwise in paid employment.

The estimated loss of housewives' activity thus derived for the sample was £74,111; this was adjusted plus or minus 50% to allow for possible differences in the distribution of employment type in women in the sample compared with the general population (Table 4.22). Costs for all reported cases were assessed at between £741,000 and £2.2 million and would be within the range estimated for Canada (Curtin; 1984). Even so, these may well be underestimates and this aspect merits further detailed study of both the time implications and effects on the family which result from housewives' illness.

The intangible costs identified by this study were between £1.6 million and £5.1 million for the sample, and between £31.8 million and £119.1 million for all reported cases (Table 4.23). These estimates were sensitive to approximated values for pain and suffering, housewives' services and deaths, and the methods by which these were evaluated. As far as possible, areas where double counting were likely to occur were identified and allowance made so as to avoid overestimation.

Estimating the annual costs of salmonellosis in England and Wales

In evaluating the total, annual cost of salmonellosis two major problems arose. The first related to the actual number of cases which occur annually and the second to how severe or mild their illness was and therefore what costs, if any, they incurred. There is currently no information available in the UK about the true incidence of salmonella infection and the underascertainment of foodborne illness, including salmonellosis, is well recognised (Chapter 1).

Estimated numbers of cases

To identify a multiplication factor, the results of a MAFF survey which included questions on recent gastrointestinal illness and food poisoning were used and applied to laboratory reported data. This approach included assumptions about the validity of interviewees answers in the MAFF survey in ascribing illness to a foodborne cause and the distribution of agents causing illness in the community compared with laboratory reports. Nonetheless, the multiplication factors (1/38 of actual cases and 1/6 treated cases reported) were in the lower half of the range (1/10 - 1/100) suggested in the Report of the Committee on the Microbiological Safety of Food (1990) and were similar to that identified by Chalker and Blaser (1988) for the USA (1/39 actual cases reported). The multiplication factor adopted was reasonable and similar to the mid-range value (1/33) used by Yule et al (1986) for Scotland.

Estimated annual costs of salmonellosis

In estimating national costs it would be inappropriate to multiply the average cost of illness (£789 minimum) by the multiplication factor derived above. The reported cases on which the costings were based were unlikely to represent the average of all illnesses which would include unreported and unascertained cases, many of which were likely to be mild. To do so would give tangible costs of about £700 million for human salmonellosis which would be criticised as an overestimate. Conversely, to ignore large numbers of unreported and unascertained cases would underestimate the economic impact of the disease.

To overcome this problem two approaches were used to identify cost bands related to the severity of illness. The first was based on demand for type of health care and was similar to that adopted by T Roberts (1989). The second utilised a severity index developed for this study which related use of services and length of illness to the patient's subjective appraisal of the number, type and severity of symptoms. Both approaches showed a relationship between increase in severity of illness and increased use of services and costs of illness. The latter approach was unique to this study and was subjected to greater scrutiny; this indicated a strong, positive correlation between length of illness, absence from work and use of medical services, with severity score. Some anomalies were identified but were explainable.

Total tangible costs identified for England and Wales were £331 million and £231 million respectively for Approaches I and II (Tables 4.24,25). The lower total for Approach II reflected the wider range of severity identified and the lower costs per case for the least severely ill. The lowest costs per case were applied to the multiplication factor, for both approaches, to assess the costs of unreported cases. For both estimates it was assumed that unascertained cases did not seek medical attention and so these costs were excluded. Production losses accounted for the highest proportion of costs (Approach I, 66%; Approach II, 70%) and the result was therefore sensitive to assumptions applied to these estimates. Public sector costs were 20% of the total under both approaches and the remainder was family related costs. Inclusion of intangible costs would add a further £32 million to £119 million. Since these estimates were based only on reported cases, they represented minimum costs. No attempt was made to estimate intangible costs associated with unascertained cases; however, these were likely to be low because of the probable mildness of illness.

The costs of human salmonella infection for England and Wales in 1988 were thus estimated to be between £263 million and £450 million. This range of costs is in the same order, but slightly higher than the equivalent costs of human salmonellosis derived by T Roberts (1989) for the USA for 1987 (allowing for differences in population size), and this may reflect the wide range of costs included in this study. Over 73% of costs were tangible costs associated with treatment and investigation of cases (public sector costs) and costs to families and the economy from sickness-related absence from work (society-related costs). Production loss was the largest single component of the total.

Comment on estimates

The methodology adopted was chosen, firstly, to enable the distribution of the costs of illness to be identified and quantified in detail, and secondly, to provide a model which would allow an extrapolation of costs taking into account a range in severity of illness. The difference in estimated tangible costs identified by the two approaches to measuring severity of illness indicated that increasing the sensitivity, by increasing the number of severity groups, will give a lower overall estimate whilst still indicating that even the least severe cases are costly, particularly in terms of production loss.

It is possible, with the large numbers of persons involved and the high estimated costs, that foodborne illness may have other, more difficult to predict, effects on the economy. Barlow (1967), in modelling the results of malaria eradication in Sri Lanka (formerly Ceylon), implied that the disease had profound effects on the economy of the country which stemmed from its effects on population size, labour input, etc. However, malaria is more endemic in the population and is more chronic in nature than salmonellosis and it is not clear to what extent large-scale sickness absence due to acute disease of short duration, such as salmonellosis, affects productivity. This is particularly so when cases are widespread, both in time and place, and length of illness relatively short. In this respect salmonellosis may also be different from, for example, influenza for which most cases occur within a few months during the Winter and Spring.

Other possible effects may include loss of consumer purchases of items such as food. However, Curtin (1984) argues that this may only represent a deferment of expenditure. This study also suggested that individuals transfer expenditure to other types of item, such as dietary supplements or leisure items, during convalescence.

The estimates do not include any allowance for the long-term sequelae of disease and probably underestimate the true cost. No attempt was made to evaluate the costs to the food industry, either in terms of sickness in animals or in terms of the effects of outbreaks on food manufacturers and retailers or of product contamination and recall on manufacturers. All these aspects have been shown to have significant economic implications (Krug and Rehm, 1983; Curtin, 1984; Todd, 1985b; Roberts et al, 1989; Sockett and Roberts, 1989; Sockett, 1991a). The economic burden of foodborne illness needs to be seen in the context of a disease which is potentially preventable and this study will form the basis of further investigations into both the costs of other foodborne and gastrointestinal diseases in the UK, and in the assessment of alternative strategies for prevention.

Costs related to all foodborne disease resulting from infective agents or their toxins may well be more than double that for salmonellosis. Previous studies in the UK indicated that although campylobacter infection is less costly on a cost-per-case basis, the larger number of cases compensated for this, indicating annual costs at least as much as for salmonellosis (Sockett and Stanwell-Smith, 1986; Sockett and Pearson, 1987; Sockett and Roberts, 1989). Costs associated with most other agents are likely to be less, both because numbers appear to be smaller and in most, illness is less severe. Nevertheless, if associated costs were only 10% of that of salmonellosis, the annual burden of foodborne illness would be between a half and one billion pounds, a comparable figure, allowing for differences in the size of population, to that estimated by T Roberts (1989) for the USA.

Chapter 5

REDUCING THE BURDEN OF SALMONELLOSIS

This thesis sought to examine factors influencing trends in human salmonellosis and the costs of illness, and to explore the cost-effectiveness of limiting the economic impact. The two approaches taken examined the cost-effectiveness of alternative methods to reduce the costs of infection, and the application of strategies to prevent human salmonellosis. Reducible costs referred to areas where the costs of investigation and treatment of cases could be minimised by changes in investigation practices or case management. The first part of this chapter considers two areas where such reductions could be achieved. This approach may have only a limited effect on the overall costs of illness. Firstly, because it does not seek to limit morbidity, only to reduce the financial impact of infections. Secondly, because the number of areas where reductions could be achieved may be relatively few. Thirdly, any reductions which could be achieved may be limited to only a proportion of the total cases occurring.

Preventable costs refer to large-scale reduction of the economic impact of salmonellosis by reducing morbidity and mortality through preventive activities applied nationally or to sectors of the food industry. Such activities would aim to limit contamination of foods and opportunities for the transmission of infection. Examples of this approach are clearly visible in the food sector, and include milk pasteurisation and the application of strict heating regimens in the canning industry. The efficacy of these processes is attested by the relatively few outbreaks due to manufactured foods compared with those due to primary agricultural products (Sockett, 1991b), and the virtual elimination of milkborne salmonella (and campylobacter) infection in Scotland following introduction of universal pasteurisation of milk (Sharp et al, 1985; Sharp, 1988). Detailed consideration of preventive activities applicable to the poultry industry and analysis of the potential economic advantages associated with specific interventions are presented in the second part of this chapter.

Reducible Costs

Two areas where costs of salmonellosis could be reduced were examined. These related to follow-up faecal sampling of cases for microbiological clearance and the use of antibiotic treatment to reduce the length of faecal excretion, particularly in individuals excluded from work.

Faecal sampling practices

The cost study showed that on average 3.2 faecal specimens were tested per case. However, persons working in "at risk" jobs had a higher average number of specimens taken (4.4) compared with cases working in all jobs (3.1 specimens) (Appendix 5a). Individuals in "at risk" jobs, accounted for 9.9% of the study sample and provided 13.8% of specimens tested. There was a wide range in the number of specimens taken per case; up to 33 for those in "at risk" jobs and up to 55 for other cases. In one example, 55 specimens were taken from an adult case and 20 specimens from three symptomless adult family contacts.

PHLS guidelines (PHLS Salmonella sub-committee, 1990) recommend that cases, once free of symptoms, need not be further tested if they practice good personal hygiene, and that specimens are not normally required from symptomless excreters with good personal hygiene. The exception to this is food handlers whose work involves touching unwrapped foods which will be consumed without further cooking, in which case three consecutive negative faecal specimens taken at intervals are usually sought.

In practice, local procedures for follow-up faecal sampling of cases and contacts may vary from the recommendations in the PHLS Guidelines. Reasons for this may include microbiological clearance of patients working in non-risk jobs, reassurance of the patient and epidemiological studies.

Benefits of reducing faecal testing.

Unnecessary tests represent an avoidable expense to the public sector and to society. To explore the potential for reducing costs of faecal testing, the savings made by reducing the number of faecal specimens taken was estimated on the basis of the following assumptions.

1. It was assumed that current practice of continuous screening of cases (to obtain 3 consecutive negative specimens) working in "at risk" jobs would continue, and that the first specimen from all cases would be referred to a reference laboratory for confirmation of serotype and phage type.

2. The average numbers of specimens per case for persons in non-risk jobs would be reduced to two and one.

3. Follow-up specimens for cases in 2 above would not be taken as a matter of normal practice.

Reducing average numbers of specimens per case to two could achieve savings of £9,706 to £28,516 (17%-38%) for the sample when compared with maximum and minimum costs of testing (Table 5.1a). Reducing the average to one would result in savings of up to £38,001 (51%) of laboratory based costs of testing for the study sample. Extrapolation to all cases in 1988 gave savings, in the range £194,114 to £760,026.

Savings on laboratory costs could be made by reducing the number of faecal specimens from case contacts. Surprisingly, the average number of specimens taken from contacts was higher than for cases (Chapter 4). The reasons for this were unclear, although a small number of contacts had very high numbers of specimens taken (range, 1-48). Data relating job specifically to contacts tested was not sought in the study but it can be assumed that at least some of those tested worked in "at risk" occupations. Table 5.1b shows the savings which could be achieved for the study sample by reducing the average number of specimens tested for contacts to three, two or one. The results indicated savings of between £1,156 and £12,658 (8%-61%) could be achieved for the sample or £23,130 to £253,170 for all reported cases in 1988.

Combining savings for cases and contacts indicated laboratory costs of faecal testing could be reduced by between £217,244 and £1,013,196 (at 1988 prices). This represented a estimated saving of 3% to 15% on public sector costs of £6.8 million for all reported cases in 1988. Further savings would result from a reduction in the number of specimens tested. For example, less time would be spent by EHOs visiting cases or contacts to deliver and collect faecal samples.

Table 5.1a

Potential Savings in Laboratory Test Costs for Cases (1988 prices)

Assumptions about numbers of specimens tested	Cost of testing (£)	Estimated saving (£)	Percentage saving
Study (average 3.2 per case)	55,507.70 - 74,317.70		
1 : average 2 per case	45,802.00	9,705.70 - 28,515.70	17 - 38
2 : average 1 per case	36,316.40	19,191.30 - 38,001.30	35 - 51

It was assumed that the average number of specimens tested remained the same for individuals in "at risk" jobs (4.4 per case) but was reduced for all others (3 per case in the study).

It was also assumed that 1 specimen per case, under both alternatives, was submitted for reference laboratory confirmation.

Table 5.1b

Potential Savings in Laboratory Test Costs for Contacts (1988 prices)

Assumptions about numbers of specimens tested	Cost of testing (£)	Estimated saving (£)	Percentage saving
Study (average 4.7 per contact)	14,224.50 - 20,614.50		
1 : average 3 per contact	13,068.00	1,156.50 - 7,546.50	8 - 37
2 : average 2 per contact	10,512.00	3,712.50 - 10,102.50	26 - 49
3 : average 1 per contact	7,956.00	6,268.50 - 12,658.50	44 - 61

It was assumed that 1 specimen per case under each alternative was submitted for reference laboratory confirmation.

Similar savings would be made by cases and contacts collecting equipment or delivering specimens to their surgery, hospital or EHD. Additional costs would be incurred in advising doctors and EHOs about recommended policy for faecal screening, but this could be minimised through use of professional journals, etc. However, further study of these possibilities is warranted

It could be argued that for cases or contacts working in jobs other than as food handlers faecal testing may be of little value for limiting further transmission of infection, particularly for those who do not have symptoms, as well as causing unnecessary expense. Additionally, it may not be necessary to test all cases in a cohort associated with an outbreak if the same salmonella has been isolated from most initial cases. Where a common exposure history and the agent causing illness have been identified, control procedures will probably have been implemented and further testing of new cases becomes academic. Exceptions to this may occur where it is important to measure the extent of spread in cases and contacts and to monitor the effectiveness of control procedures where individuals may be at particular risk if infected, for example patients in hospital.

A further anomaly occurs where a single clearance specimen may be required in, for example, persons working in occupations other than as food handlers where there is a risk of transmitting infection. Evidence suggests that a single negative specimen, as required by some authorities, or even three consecutive negative specimens are unlikely to be a good indicator of clearance and may give a false sense of security (Bille et al, 1964; McCall et al, 1966; Bailey et al, 1972). Concentration on hygiene standards, with sanitary disposal of excreta or contaminated materials, may be more effective in reducing risk.

Buchwald and Blaser (1984) reviewed 32 studies of salmonella carriage and excretion and concluded that follow-up cultures may only be indicated for patients at high risk of developing biliary disease. Infected food handlers were thought to constitute only a minimal risk, on the basis that although about 200,000 persons in the USA may be excreting salmonella at any one time, very few outbreaks were recorded in which food handlers or health care personnel were shown to be the source of infection. Of 126 outbreaks recorded over 10 years in

England and Wales in which infected food handlers were recorded, in only two were asymptomatic excreters the likely source of contaminated food (Roberts, 1982). Thus the rationale for follow-up cultures in all but some specific situations is at best weak.

Costs of excluding persons working in "at risk" jobs

It is currently recommended that persons with salmonella infection and working in "at risk" jobs should be excluded from work*. Since faecal excretion can last for several weeks and, in a small proportion of cases, months or years (Buchwald and Blaser, 1984), this could result in considerable costs, in compensation payments, to the local authority concerned. In this study 39 cases (2.6%) were excluded and missed an average of 49 working days (range 2-119 days) (Chapter 4). Costs of local authority and laboratory investigations of £21,894 were estimated and included compensation payments of £11,494; that is 12-13% of all local authority costs and 7% of public sector costs (Chapter 4). Some local authorities may be insured against such losses (C Majewski, DoH, personal communication). However, this was not known for the local authorities in the study and the assumption was made that most were not and that there was, in any case, a net cost to society; compensation via insurance effectively transferring the cost from one sector to another. Obviously, limiting the time excluded from work would reduce the costs to local authorities, associated with this measure.

Economic benefits of limiting the period of excretion.

The economic benefit of using ciprofloxacin therapy to reduce excretion time of salmonellas, thereby enabling an early return to work for adults in "at risk" jobs was explored for the 39 excluded cases in the study using the following options.

*Exclusion is carried out by local authorities enacting the Public Health (Control of Diseases) Act 1984, Section 20(1), the Food Act 1984, Section 28(1) or the Public Health (Infectious Diseases) Regulations 1988 (Schedule 4). Section 20(2) of the Public Health Act 1988 also makes provision for the local authority to compensate financial loss incurred by individuals excluded from work. Compensation would normally be based on the patient's average earnings less any money received from the employer or as sickness benefit. The method of calculation and payment may vary with the local authority. Normally compensation ceases when the individual is no longer regarded as being at risk of transmitting infection and returns to work. This is usually on the basis of recovery from symptoms and faecal clearance, i.e. the patient is no longer adjudged to be excreting the organism following demonstration of three consecutive faecal specimens negative for salmonellas.

1. Exclusion until faecal clearance (3 consecutive negative specimens) following ciprofloxacin treatment.

2. Allowing individuals to return to work 48 hours after ciprofloxacin treatment was commenced plus demonstration of a single negative specimen, with three consecutive negative specimens required at the end of the course.

Calculations were based on a recommended dose of 1,000 mg ciprofloxacin per day for five or 10 days (cost: £15 per 5 days) (BMA and the Royal Pharmaceutical Society of Great Britain, 1989). Although there is discussion about recommended regimens, doses of 1,000 mg to 1,500 mg daily for one to two weeks have been reported effective; salmonella excretion ceased after 48 hours and diarrhoea resolved within two days of treatment being commenced (Pichler et al, 1986; Lahdevirta, 1989).

Public sector costs associated with exclusion. Exclusion costs for 39 cases are shown in Table 5.2. Other EHD costs associated with these cases were identified and average daily costs calculated. The costs of treatment and follow-up of excluded cases derived from the survey results (Chapter 4) were estimated at £21,894.30 (average £561.39 per case). Under the options in Table 5.2 these could be reduced to £3,695 to £6,424, giving estimated savings of £15,471 to £18,199. When extrapolated to all reported cases in 1988, estimated savings for these costs were twenty times greater and in the range £309,412 to £363,981.

Length of exclusion and other EHD costs had the biggest influence on expenditure under Option I, accounting for about 70% of the total. Antibiotic treatment costs were 11% to 18% of the total. Extending treatment from five to ten days increased total expenditure by 18%, over half (59%) of which was increased drug costs. Under option 2 only length of treatment was allowed to vary and thus total costs were sensitive to the costs of therapy. Investigation of alternative regimens should indicate the optimal dosage and exclusion period; nevertheless the results indicated that savings of between 71%-83% on the costs of environmental health follow-up may be possible for cases excluded from work.

The shorter treatment period may also reduce the possibility or

Table 5.2

Costs of Antibiotic Treatment and Environmental Health Follow-up of Excluded Cases Receiving Ciprofloxacin, and Estimated Savings on Conventional Management

(at 1988 prices)

Number of days of treatment	Cost of treatment	Cost of exclusion	Other EHD costs	Cost of faecal tests	Total costs	Estimated saving† (39 cases)	Estimated saving (national)
Option I[1]							
5 days	585	2,359.50	1,661.40	830.70	5,436.60	16,457.70	329,154
10 days	1,170	2,595.45	1,827.54	830.70	6,423.69	15,470.61	309,412
Option II[2]							
5 days	585	1,171.95	830.70	1,107.60	3,695.25	18,199.05	363,981
10 days	1,170	1,171.95	830.70	1,107.60	4,280.25	17,614.05	352,281

† Estimated investigation and exclusion costs of 39 cases in the study were £21,894.30; subtracting "Total costs" for each Option gave "Estimated savings"

[1] *Option I* : cases treated for 5 or 10 days (500 mg bds) followed by faecal clearance by 3 consecutive negative specimens over a further week before return to work;

[2] *Option II*: cases treated for 5 or 10 days (500 mg bds) but returned to work 48 hours after treatment commenced and 1 negative specimen (assumed to take about 1 week), with 3 consecutive negative specimens to confirm clearance after treatment is completed.

severity of side-effects due to ciprofloxacin. Treatment of severe side-effects, such as PMC would probably negate any financial benefits of ciprofloxacin therapy if even a few cases resulted, in addition to the discomfort experienced by the patient. Also, not all cases are cleared from excretion of salmonellas by ciprofloxacin therapy. Further modelling of reduction of excretion for certain "at risk" groups would need to take these aspects into consideration.

The savings achieved could be increased further if the necessity of multiple clearance specimens could be reduced. It should be noted that this change in management is only advocated for adults in "at risk" jobs in order to return them to work and to avoid the financial and social effects of exclusion. All other uncomplicated cases of gastroenteric illness would continue to be managed as before.

Production loss associated with exclusion. Returning excluded individuals to work may also reduce production losses incurred by employers. Based on average, non-gender-adjusted rates with labour costs added (£51.63), production loss resulting from 1,901 days (average 48.7 days) off work was estimated at £98,148.63. Potential savings based on Options I and II are shown in Table 5.3. These showed that if average days off work were reduced to 5 to 12 then savings in production losses of £74,502 to £88,597 could be achieved. When extrapolated to all cases in 1988 (20 times greater), this represented savings in production losses of £1,490,042 to £1,771,942.

This represents a minimum saving, since the cost to an employer of having a member of staff excluded for weeks or months may also include costs of temporary staff to cover absence or the cost of seeking new employees. Although more difficult to quantify, the benefits to the employee of an early return to work may also be significant. These may include, not only financial savings of costs incurred through doctors visits, delivering specimens, leisure items, etc., but also the reduction of worry to the individual and his or her family about making ends meet and the potential loss of employment.

Summary

These two models indicate that current faecal testing and exclusion

Estimated Production Loss Savings

Associated with Changed Management of Excluded Cases

Estimated average days off		Estimated days saved on average days off in sample	Estimated production loss saved (£)*
Option I:	10	39	78,529.23
	12	37	74,502.09
Option II:	5	44	88,597.08

* based on non-gender-adjusted rate modified to include employment costs (£51.63 per day) for 39 cases

practices result in large and potentially reducible costs to the public sector and industry. This is in addition to any worry, inconvenience and cost to the case and his or her family. Unnecessary faecal testing of cases and contacts results in costs to EHDs from the follow-up of cases and to laboratories where tests are performed. Where the person under investigation has an "at risk" job, he or she may be excluded from work for long periods. This is despite evidence that asymptomatic excreters present only a minimal risk of transmitting infection, that ciprofloxacin therapy may be effective in reducing the length of salmonella excretion, that PHLS guidelines imply a more conservative approach to faecal testing, and evidence that unnecessary testing and prolonged exclusion from work is expensive and may cause economic and social hardship. These findings suggest a re-appraisal of current faecal testing and exclusion practices is warranted.

Such re-appraisal is compatible with current cost containment in the health sector (Evans et al, 1991; Welch, 1991). Emphasis has been placed on reducing morbidity through preventive activities and on the reduction of avoidable costs through audit, at one level, of the way care is managed (Hughes, 1991; Melnick, 1991) and, at another level, in the delivery of specific tests, services or treatments (Foulke and Siepler, 1990; Barriere, 1991; Winkelman et al, 1991). Some caution is required when advocating changes in practice or policy that costs are not just re-allocated. Wickizer et al (1991) indicated that programmes to reduce in-patient costs may result in increased out-patient costs. It is not obvious that this would happen with faecal testing and exclusion; as such these areas may offer real potential savings.

Preventable Costs

This section seeks to model the potential benefits achieved by reducing morbidity due to salmonellosis by prevention of infection. The evidence presented in Chapters 3 suggested that the risk factors in transmission of salmonellosis were firstly, related to contaminated food particularly poultry meat and products; secondly, to travel abroad, although many of these infections were probably foodborne; thirdly, to other mechanisms such as person-to-person spread, contaminated medical equipment and infected pets (*see footnote next page). In terms of preventive activities, reduction of foodborne transmission offers the greatest potential for reducing the burden of illness.

The resources available to invest in preventive activities are likely to be limited. Thus, such activities should be targeted at the factors which have greatest influence, are amenable to modification (Chapter 3) and to select the intervention which gives the best possible return on investment. One way to achieve this is to measure the economic benefits which arise from specific interventions. Thus approaches to assessing the costs and benefits which might accrue from two primary prevention measures aimed at poultry-borne salmonella infection are modelled.

To effectively reduce the proportion of chicken carcasses contaminated with salmonellas, thereby reducing the risk of human infection, either poultry entering the production cycle need to be rendered as salmonella free as possible, with substantial effort made to minimise the risk of infection during rearing and processing, or the end product should be rendered salmonella free prior to sale. The costs and benefits of two approaches, based on gamma irradiation post processing to limit the level of contamination of the final product and competitive exclusion (CE) to inhibit colonisation of poultry by salmonellas are considered. Both models incorporate a series of assumptions about the levels of reduction in human salmonellosis which may be achieved.

Irradiation

In comparing the costs of irradiating poultry with the benefits gained from a reduction in salmonella infection a number of assumptions were made. The capital and maintenance costs of an irradiation plant were adapted from costs given by Yule et al (1986), and together with additional assumptions about costs and methods of operation, which were incorporated in the model presented, are described in Appendix 5b.

Radiation levels.
Irradiation costs were based on the use of a gamma-ray (Cobalt 60) source giving an irradiation dose of 3 kiloGrays (kGy). At 3 kGy 99.99%

*It should, however, be noted that although some of these latter may only make a limited contribution overall, in specific circumstances they may be a major risk factor. For example person-to-person transmission in hospitals (Joseph and Palmer, 1989).

of salmonella cells are inactivated under optimal conditions (Kinzel, 1991). This is less than half the dose permitted for poultry in the UK*. Even at lower doses, eg. 0.9 kGy, a 6.4 log reduction in the number of cells in deboned chicken meat at 0°C was demonstrated (Thayer et al, 1991); surviving cells were also more heat sensitive and remained so for at least six weeks (Thayer et al, 1991). Mulder et al (1977) showed doses of 2.5 kGy were effective at destroying salmonellas. Some serotypes appear more resistant than others and increased survival has been reported for both **S. enteritidis** and **S. panama** (Mulder, 1976; Thayer et al, 1990). Survival appears to be temperature related and salmonellas and other bacteria are more resistant to radiation at temperatures below -20°C although viable salmonellas on carcasses stored at -18°C after irradiation (at 2.5 kGy) died off (Thayer et al, 1990; Thayer and Boyd, 1991a; Thayer and Boyd, 1991b; Mulder,1982). Thus a combination of irradiation then freezing could achieve marked reductions in salmonella counts in poultry.

Estimated costs and benefits of irradiation.

The costs of irradiation included the capital costs related to buildings, land and equipment, and recurrent expenditure associated with overheads and operating expenses. In addition, allowance was made for additional transport costs to the poultry industry as well as an annual allowance for product promotion. A weighting of 25%, 50% and 75% of the basic costs was added to incorporate any unforseen plant and operating costs. The stream of benefits of irradiation (costs of salmonellosis less costs of irradiation) are presented in Table 5.4. These are presented as the net present values (1988 prices) discounted over 15 years (the life expectancy of an irradiation plant) using a range of discount values and for a series of assumptions about the expected level of reduction in human salmonellosis**. The results indicated that only under the most severe assumptions about irradiation costs and effectiveness was the net benefit negative. Thus, for example, using the discount rate of 5% recommended by the Treasury

*A does of 7kGy is permitted for poultry under The Food (Control of Irradiation) Regulations 1990.

**The stream of values (not discounted) relating to costs of irradiation and the range of benefits resulting from reductions in human infections of 10%, 25% and 50% (assuming these are the costs avoided if these levels of reduction in salmonellosis are achieved, then they are a measure of benefits) are presented, together with the net benefits, in Appendix 5c.

Table 5.4

Flow of Benefits of Poultry Irradiation under a Series of Assumptions about Irradiation and Salmonella Costs

Discount rate	Costs of irradiation*	Minimum salmonella cost (1988 prices) Reduction in salmonellosis			Maximum salmonella cost (1988 prices) Reduction in salmonellosis		
		10%	25%	50%	10%	25%	50%
3%	Basic cost	113,976,622	540,036,487	1,250,136,262	236,937,622	847,438,987	1,864,941,262
	Cost + 25%	77,658,034	503,717,899	1,213,817,674	200,619,034	811,120,399	1,828,622,674
	.. + 50%	41,339,447	467,399,312	1,177,499,087	164,300,447	774,801,812	1,792,304,087
	.. + 75%	5,020,859	431,080,724	1,141,180,499	127,981,859	738,483,224	1,755,985,499
5%	Basic cost	94,461,849	472,094,874	1,101,483,249	203,446,849	744,557,374	1,646,408,249
	Cost + 25%	60,631,318	438,264,343	1,067,652,718	169,616,318	710,726,843	1,612,577,718
	.. + 50%	26,800,787	404,433,812	1,033,822,187	135,785,787	676,896,312	1,578,747,187
	.. + 75%	-7,029,744	370,603,281	999,991,656	101,955,256	643,065,781	1,544,916,656
7%	Basic cost	79,364,989	419,534,434	986,483,509	177,537,989	664,966,934	1,477,348,509
	Cost + 25%	47,459,248	387,628,693	954,577,768	145,632,248	633,061,193	1,445,442,768
	.. + 50%	15,553,507	355,722,952	922,672,027	113,726,507	601,155,452	1,413,537,027
	.. + 75%	-16,352,234	323,817,211	890,766,286	81,820,766	569,249,711	1,381,631,286
10%	Basic cost	59,108,778	349,011,468	832,182,618	142,774,778	558,176,468	1,250,512,618
	Cost + 25%	29,785,624	319,688,314	802,859,464	113,451,624	528,853,314	1,221,189,464
	.. + 50%	462,469	290,365,159	773,536,309	84,128,469	499,530,159	1,191,866,309
	.. + 75%	-28,560,685	261,042,005	744,213,155	54,805,315	470,207,005	1,162,543,155

* Capital costs of plant (£57,064,560) and land (£650,000) and recurrent expenditure on maintenance, transport and product promotion (£9,136,940) at cost and cost plus 25%, 50% and 75%. Details of the flow of costs and benefits for each assumption are given in Appendix 5c. The flow of benefits are presented as the net present value discounted over 15 years.

for the appraisal of public works (DHSS, 1987) benefit was only negative for the highest cost of irradiation (cost + 75%) at the lowest assumption for cases avoided, at minimum cost of salmonellosis. Under these assumptions the point at which benefits broke even with costs occurred when a reduction of between 10% and 25% of cases was achieved for the severest assumptions of irradiation cost and otherwise at a level of less than a 10% reduction in cases. These results were similar to findings by Yule in a recent study of the costs and benefits of poultry irradiation (B. Yule, personal communication). For the maximum cost of salmonellosis no negative benefit was observed for the assumed levels of reduction in salmonellosis.

The results also indicated that even for a modest reduction in human salmonella infection of only 25%, the minimum benefits which would accrue under all assumptions of irradiation cost and discount rates would be substantial (£261 million - £540 million over 15 years) and there would be considerable scope for increasing some elements, eg. doubling promotional costs, without significantly affecting benefits.

These results were based on the public sector and society costs of salmonellosis; inclusion of intangible costs would have increased the net benefit and would have countered any negative benefits.

Competitive Exclusion (CE)

An alternative approach to irradiation would be to reduce the levels of salmonella contamination in poultry during breeding and rearing by the combined use of antibiotic treatment and CE treatments. Thus fewer birds with lower levels of contamination would enter the processing plant. This method has the advantage that the product is more likely to be acceptable to the consumer although the reductions in human infection would probably be lower than for irradiation*.

*Competitive exclusion was developed in Finland in the 1970's in response to outbreaks of S. infantis infection (Nurmi and Rantala, 1973). The principle of this method is to establish an adult intestinal flora in young chicks as early as possible. This was achieved by oral administration of the gut contents of suitable adult birds (Nurmi et al, 1977) or by defined mixtures of intestinal bacteria (Stavric et al, 1985; Mead and Impey, 1987). Once established, the normal gut flora inhibits salmonella colonisation and reduces the incidence of carriers and the numbers of salmonellas shed (Mead and Impey, 1987).

The approach considered in this section compared various options for reducing salmonella carriage in both breeder and broiler (chicken reared for the table) flocks. These were based on combinations of antibiotic and CE treatment of breeder and broiler flocks and are described in Appendix 5d. Rather than attempt to estimate the levels of reduction of human salmonella infection which could be achieved, for which little reliable information is available, I have sought to identify the level of reduction above which these options would have a positive cost benefit in terms of the number of cases avoided. Thus the cost-benefits of reducing human infections in the range of 1% to 10% were considered although Curtin (1984) suggested that reductions in human infection as high as 40% or more may be possible. As with the appraisal of irradiation a number of assumptions were made and these are described in Appendix 5d.

Flow of benefits from the use of CE in poultry production.

The results of the option appraisal and the flow of benefits based on 1988 prices are shown in Table 5.5. Option 1, treatment of breeder flocks only, was likely to be the least effective in terms of reducing human illness since it included no measures to limit infection in broiler flocks. However, even a modest reduction of 1% in human infection produced a positive net benefit. The treatment of the broiler chicks greatly increased the costs of the option implementation and any option using this approach would require a reduction in human illness of 5% (minimum cost of salmonellosis; or 4% based on maximum costs) to reach break-even point. Inclusion of intangible costs would have resulted in a shift to the left of the net benefits shown in Table 5.5 equivalent to 1%; ie. a break even point at a 4% reduction in human illness would shift to a 3% reduction.

The insensitivity to the break-even point in the reduction of human illness for options 2-4 resulted entirely from the dominance of the costs of treating the broiler flocks. However, this result has to be seen in the context of a greater potential level of success in reducing human infection using these options.

A similar pattern was obtained when the comparisons were made using the maximum costs of human illness, although the break-even point for options 2 and 3 was a 4% reduction in human infections and for option

Table 5.5

Estimated Benefits from the Use of Competitive Exclusion in Poultry Flocks

Assuming Reductions in Human Salmonellosis of One to Ten Per Cent : England and Wales

Cost of option implementation	Costs of salmonellosis for cases avoided (at 1988 prices)					
	Minimum costs					
	1%	2%	3%	4%	5%	10%
1. 669,240	2,310,000	4,620,000	6,930,000	9,240,000	11,550,000	23,100,000
net benefit	1,640,760	3,950,760	6,260,760	8,570,760	10,880,760	22,430,760
2. 10,261,680	2,310,000	4,620,000	6,930,000	9,240,000	11,550,000	23,100,000
net benefit	-7,951,680	-5,641,680	-3,331,680	-1,021,680	1,288,320	12,838,320
3. 10,930,920	2,310,000	4,620,000	6,930,000	9,240,000	11,550,000	23,100,000
net benefit	-8,620,920	-6,310,920	-4,000,920	-1,690,920	619,080	12,169,080
4. 9,815,500	2,310,000	4,620,000	6,930,000	9,240,000	11,550,000	23,100,000
net benefit	-7,505,500	-5,195,500	-2,885,500	-575,500	1,734,500	13,284,500
	Maximum costs					
	1%	2%	3%	4%	5%	10%
1. 669,240	3,310,000	6,620,000	9,930,000	13,240,000	16,550,000	33,100,000
net benefit	2,640,760	5,950,760	9,260,760	12,570,760	15,880,760	32,430,760
2. 10,261,680	3,310,000	6,620,000	9,930,000	13,240,000	16,550,000	33,100,000
net benefit	-6,951,680	-3,641,680	-331,680	2,978,320	6,288,320	22,838,320
3. 10,930,920	3,310,000	6,620,000	9,930,000	13,240,000	16,550,000	33,100,000
net benefit	-7,620,920	-4,310,920	-1,000,920	2,309,080	5,619,080	22,169,080
4. 9,815,500	3,310,000	6,620,000	9,930,000	13,240,000	16,550,000	33,100,000
net benefit	-6,505,500	-3,195,500	114,500	3,424,500	6,734,500	23,284,500

See Appendix 5c for detailed description of options 1-4 and assumptions made about poultry production and treatment costs.

4 a 3% reduction. Thus CE in combination with antibiotic treatment and applied either to breeder or breeder and broiler flocks potentially offers a high benefit to cost ratio at relatively modest levels of reduction in human infections under the assumptions made.

Summary

The cost benefit analysis indicated the benefits flowing from a reduction in salmonellosis following irradiation of poultry meat are likely to be high. Thus providing scope for expenditure to promote the product and inform the public about the safety and acceptability of irradiated foods. However, the choice of a procedure to reduce or eliminate salmonella contamination is governed not only by its effectiveness, but also by the requirements of the retailer, its cost and the acceptability to the consumer of any effect of the treatment on the appearance, smell or taste of the product. These effects may be perceived rather than actual but if it results in consumer resistance, as is currently the case with irradiated food, the process is unlikely to be taken up readily by the food industry. Some of the main areas of consumer concern relating to irradiation are described in Appendix 5e. It has been suggested that the scientific community has a contribution to make to this education process (Mossel, 1966). At least three other studies, those of Curtin (1984) in Canada, Krug and Rehm (1983) in Germany and Yule et al (1986) in Scotland also confirm the potential benefits of poultry irradiation.

Food irradiation is approved in several countries and specific approval for irradiation of poultry was given by the United States FDA in 1990 (Kinzel, 1991) and in the UK under The Food (Control of Irradiation) Regulations, 1990. Thus a major and effective tool for control of salmonellosis is now available. The main stumbling block appears to be consumer resistance which may be difficult to overcome and very slow to change, although similar resistance to new techniques of rendering food safer have been recorded in the past. Adams (1947) in describing the adoption of pasteurised milk in the USA stated, "its general acceptance has been achieved, in many instances, against strenuous opposition of special interests, politicians and others whose reasoning ignored sound scientific facts and was largely emotional." Many of the objections to pasteurisation itemised by Adams were similar to those currently promulgated by objectors to irradiation and included queries about changes in the nutritional value of pasteurised milk, its taste, the fallibility of the process, effects on the price of the product and the untreated product being more 'healthy'. Similar objections were put forward in the UK and while universal pasteurisation was eventually introduced in Scotland in 1983 (Sharp, 1988), this is still not the case in England and Wales.

Many of the supposed or identified effects of irradiation on food are observed in foods processed by other treatments which are, however, acceptable because of their traditional nature. Adams (1947) recommended the effective countering of each specific argument and public education to overcome objections. The effectiveness of this approach has been demonstrated in South Africa where more than 90% of consumers surveyed were willing to use irradiated produce (Webb, 1983). Public education was supported by consumer organisations, leaflet distribution and in-store information desks manned by expert advisors.

Reducing the number of contaminated birds by CE, although unlikely to be as effective as irradiation, could have an important impact on the levels of human salmonellosis. Todd (1980) observed that policies designed to reduce the numbers of infected birds in breeder flocks and the maintenance of high standards of hygiene at every level of production were credited with bringing about major reductions in numbers of contaminated birds and human infections in Sweden, Denmark and Switzerland in the 1970's. These policies, largely based on screen and destroy and quarantine approaches, may be relatively expensive because of the potentially high level of wastage, particularly in the initial stages, and the need for adequate compensation for farmers to encourage compliance. Adoption of CE could potentially achieve a similar good result but avoid the wastage and cost.

These analyses indicate considerable benefits could accrue from preventing poultry-borne salmonellosis, and that irradiation and CE could make an important contribution to reducing the economic and social effects of this disease. Although irradiation is expensive, its high level of efficiency in reducing contamination would result in a sharp decline in poultry-borne salmonellosis if adopted on a large scale. The effectiveness of adopting this approach on a smaller scale or for specific types of poultry only was not considered in this study but may warrant further exploration. Consumer opposition, however, may delay introduction for a long time to come. In contrast, CE offers a less effective but probably more acceptable alternative which would need to achieve only a modest reduction in human infection to give a positive return on its implementation.

These results were based on assumptions about the implementation of these strategies and their effects on trends in human infection. More sophisticated appraisal would need to identify knock-on effects of implementation to the poultry industry and to consider in detail the cost and benefits of these effects. For example, to what extent would introduction of irradiation affect the frozen poultry sector because of the extended shelf life of irradiated chicken? Would introduction of CE increase productivity by reducing chick mortality? Would poultry producers have to absorb the costs of interventions thereby decreasing their profit margins or would the cost be spread across the retail industry also?

Would consumers be willing to pay more for safer chickens? A study in the USA showed that over half of those interviewed would be willing to pay up to 17 cents per pound extra for disease free chicken (Smallwood, 1989). Different options may be available for the administration and monitoring of CE; for example, to ensure compliance and consistency there may be advantages in MAFF administering the antibiotic and CE treatment of either or both breeder and broiler flocks.

Other possible methods for reducing salmonella infection of live birds, limiting cross-contamination during processing or decontamination of the meat products have been put forward in recent years. Thus, in addition to showing the benefits of prevention and indeed, to identifying the benefits accruing to specific preventive activities, as shown in this study, the models presented could be adapted for comparing the relative benefits of alternative approaches to reducing contamination at one particular stage or of intervening at different stages in the production cycle. Such Economic Analysis of Preventive Strategies (EAPS) could provide a powerful adjunct to the HACCP approach which seeks to identify and assess the microbiological hazards and risks associated with food production processes and identify points of control (International Commission on Microbiological Specifications for Foods, 1988; Tompkin, 1990). Thus EAPS would assist the process of deciding both at which point intervention provides the greatest benefit and which alternative procedure would be most cost-effective at that point.

CONCLUSIONS

This is the first detailed national study of the costs of human salmonellosis reported in England and Wales and estimated tangible costs for 1988 were between £231 million and £331 million. Additional intangible costs related to the value of lives lost and to the general discomfort of illness (pain and suffering) were estimated at £32 million to £119 million.

Although high these estimates should be seen in the context of the costs and benefits of other activities in the health sector. They should also be viewed as minimum costs since no attempt was made in this study to quantify costs related to long term sequelae of disease; this aspect should be explored further. Nevertheless these estimates provided a basis for analysis of the benefits of preventive activities.

The study demonstrated the value of cost-of-illness methodology in identifying and quantifying the social and economic effects of salmonellosis. Where necessary these results were combined with willingness to pay estimates and surrogate measures of costs to further delineate the size and variety of types of cost associated with salmonella infection. This approach provides a model for the further exploration of the costs of other infectious diseases and has been incorporated into a national study of the costs of infectious intestinal disease.

The study incorporated two approaches to providing a range of costs related to the severity of infection based on type of treatment demanded and a severity index related to subjective assessment, by the case, of how ill they were. This latter approach showed a high degree of correlation between severity score and level and amount of treatment demanded. Identification of the distribution of costs according to severity of infection was essential to the extrapolation to national costs particularly where this related to unascertained cases which were likely to be only mildly ill in the main.

The national costs derived were used as a basis for modelling the potential to limit the costs of salmonellosis. Two approaches to this were explored. The first examined the potential for reducing present costs by changes in the way cases are managed. The results of this part of the study indicated that limited savings would accrue from reducing the numbers of faecal specimens tested and from reducing time off work.

The second approach examined the cost-effectiveness of preventing human illness by specific measures applied to the poultry industry. The results suggested that on economic grounds alone there is a strong case for the introduction of irradiated poultry as a means of reducing human salmonella infection. Further benefits would accrue from the elimination of other bacteria such as campylobacter, another frequent contaminant of poultry, and possibly **Listeria monocytogenes**. The process also has the advantage that it can be carried out after packaging thus avoiding the possibility of recontamination.

The major objection to such a move at present appears to be consumer resistance to the product despite government approval for the sale of irradiated foods, including poultry, in 1990. Therefore, a second approach utilising CE and antibiotic treatment of live birds was examined. Although likely to be less effective than irradiation, only modest reductions (3%-4%) in human salmonellosis were required to achieve a positive benefit under the assumptions made in this study.

A detailed analysis of data on food poisoning in general and salmonellosis in particular covered a period of 30 years. Trends in salmonella infection were shown to have been influenced by a limited number of serotypes, many of which were particularly associated with poultry or cattle. In recent years these trends have been influenced almost entirely by reporting of **S. enteritidis** infection associated with contaminated poultry and egg products. A number of other factors, both intrinsic and extrinsic to food production, for example microbial quality of food, animal hygiene, meat consumption patterns and ambient summer temperature, have influenced reported trends and these should be considered in assessing the risks associated with particular foods. Using this approach poultry and egg products were identified as particular targets for preventive activities.

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Appendix 1a

INFECTION IN ANIMALS

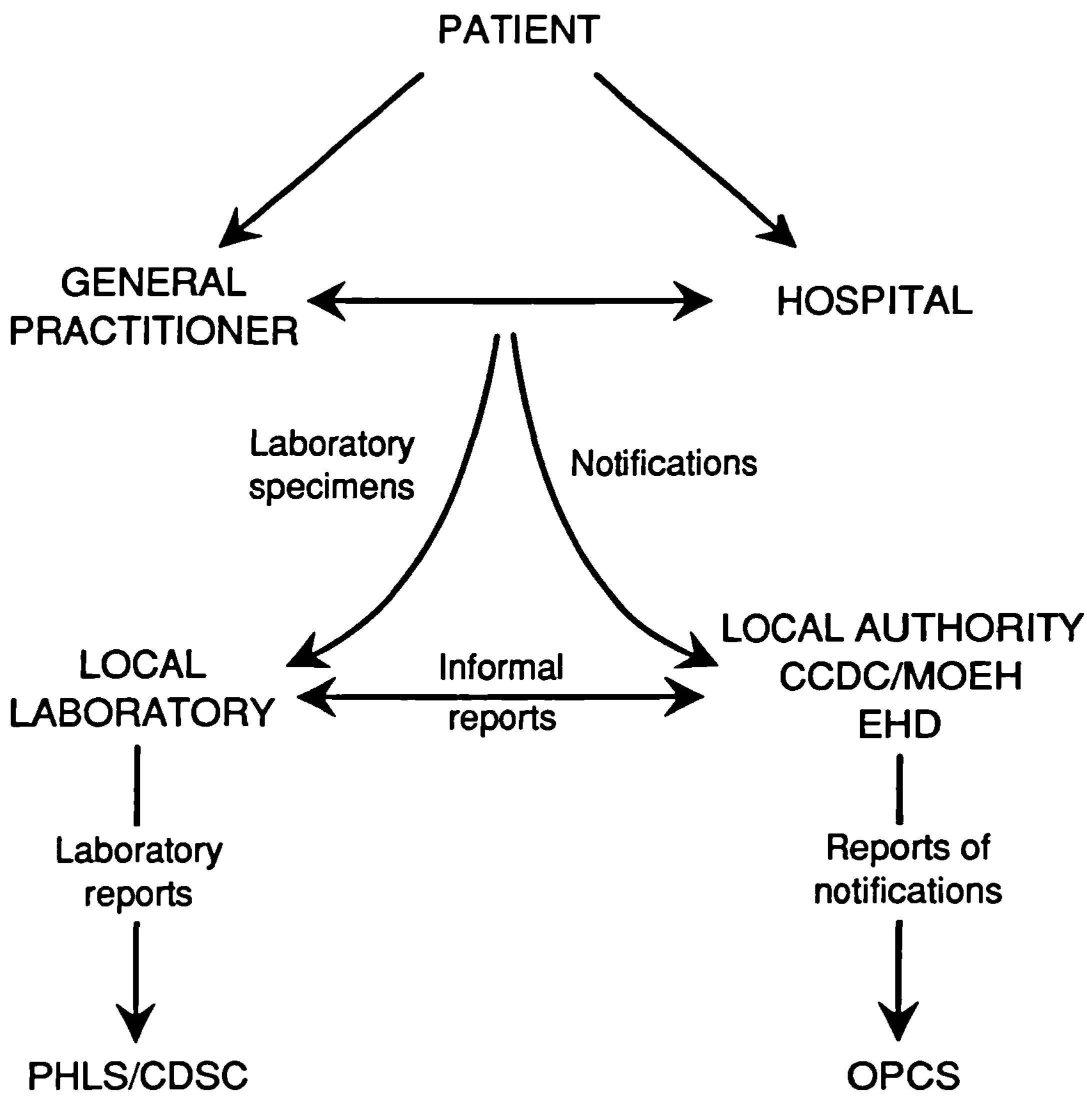
Animal salmonellosis manifests as either septicaemia, acute or chronic enteritis, or may be sub-clinical (Acha and Szyfreo, 1980). Contaminated animal feed is thought to be a major vehicle for infection of domestic food animals (Report of a Working Party of the PHLS, 1961; Dawkins and Robertson, 1967; Riley, 1969; PHLS, 1972) and epidemiological evidence suggests a high proportion of human infection may be indirectly associated with contaminated animal feeds (Anon, 1974; Lee, 1974; Report, 1965). The disease in cattle is marked by profuse diarrhoea and fever and may cause abortion in pregnant cows. On recovery the animal may become a carrier. Calves are more susceptible than adults, with high mortality in very young animals, although the carrier state is less common. The serotypes mainly responsible for clinical illness are **S. dublin** and **S. typhimurium.**

Pigs may host numerous serotypes and infection with **S. cholerae-suis** is frequently septicaemic. Young pigs aged two to four months are most susceptible and epidemic outbreaks are most likely to occur among swine in this age group. Clinical salmonellosis is not common among sheep and goats, however **S. typhimurium** is the most common serotype found in cases of salmonella gastroenteritis and **S. abortus ovis** may cause gastroenteritis and abortion.

Two serotypes, **S. gallinarum** and **S. pullorum,** are adapted to domestic fowl and may cause serious economic loss, particularly among young birds. Other serotypes are frequently isolated from poultry and poultry products and as such are of most importance in terms of human public health. Although infection with these other serotypes is often sub-clinical in adult birds, young birds may have symptoms which include anorexia, profuse diarrhoea and increased water consumption (Acha and Szyfreo, 1980). Occasionally one specific type of salmonella may predominate as a contaminant of poultry, e.g. **S. hadar** in turkeys in the late 1970s (Rowe et al, 1980) and **S. enteritidis** in poultry in the late 1980s (Agriculture Committee First Report, 1989). **S. enteritidis** has not only become a widespread contaminant of poultry, but has also acted like a host-adapted species, causing systemic infection. In particular, infection of ovaries and the oviduct may have led to vertical transmission of infection from parent to broiler and layer flocks and contributed to increased incidence of human salmonellosis associated with eating eggs and egg-containing products. Animals, and poultry in particular, carrying non-host adapted serotypes in the gut may exhibit low levels of excretion (Kirby, 1985; Bell et al, 1988). However, mixing and crowding of animals during transport and marketing can markedly increase the risks of spread of the organism, particularly in calves and both markets and transport vehicles have been shown to be frequently contaminated with salmonellae (Anderson et al, 1961; Kirby, 1985; Wray et al, 1991).

Appendix 1b

Sources of Information on Food Poisoning and Salmonellosis in England and Wales



PHLS	Public Health Laboratory Service
CDSC	Communicable Disease Surveillance Centre
CCDC	Consultant in Communicable Disease Control
MOEH	Medical Officer for Environmental Health
EHD	Environmental Health Department
OPCS	Office of Population Cencuses and Surveys

Appendix 1c

MAIN SOURCES OF DATA ON FOODBORNE ILLNESS AND SALMONELLOSIS

Statutory notifications

Cholera was the first infectious disease to be made statutorily notifiable in England and Wales under the Public Health Act of 1875. This Act was later extended to include other infectious diseases by the Infectious Diseases (Notifications) Acts 1889 and 1899. Currently there are 29 diseases which are notifiable in England and Wales, including food poisoning.

Although the Local Government Board published a memorandum on the investigation of suspected outbreaks of food poisoning in 1911, food poisoning was not made notifiable until 1938, under section 17 of the Food and Drugs Act 1938 (Cockburn, 1960). These data were not collected and analysed centrally until 1949 and statistics were not published regularly until that year. There were 6,111 notifications recorded in 1949. Notifications of food poisoning were first mentioned in the annual Statistical Review of the Registrar General in 1950.

Section 48 of The Health Service and Public Health Act 1968 defined the legal obligation of the clinician:

"If a duly qualified medical practitioner becomes aware, or suspects, that a patient whom he is attending within a district of a local authority is suffering from a notifiable disease or from food poisoning, he shall, unless he believes, and has reasonable grounds for believing, that some other such practitioner has complied with this sub-section with respect to the patient, forthwith send to the Proper Officer of that district a certificate stating:

a) the name, age and sex of the patient and the address of the premises where the patient is;
b) the disease or, as the case may be, particulars of the poisoning from which the patient is, or is suspected to be, suffering and the date, or approximate date, of its onset."

Notification is therefore based on the suspicion that a patient has food poisoning (or other notifiable disease) and does not require a laboratory confirmation of diagnosis, the objective being to provide the local public health doctor with immediate information to enable action, such as contact tracing or investigation of the source of infection, to begin as quickly as possible. For this reason the clinician can "notify" by telephone initially, although he or she will later be required to send a written certificate. Notifications compiled by the Proper Officer are "returned" weekly to OPCS for analysis and statistics are published regularly by the Office of Population Censuses and Surveys (OPCS) in weekly, quarterly and annual reports.

Laboratory reports

Laboratory reporting of individual cases and outbreaks of salmonella infection provides the most detailed information currently available on human salmonellosis. The development of food poisoning and salmonellosis surveillance in England and Wales, based on laboratory reporting, began with the creation of the Emergency Public Health Service in 1939, which became permanently established as the Public Health Laboratory Service (PHLS) in 1946 (Williams, 1985). Microbiologists in public health and, later, hospital laboratories, were asked to report cases and outbreaks of infectious diseases, including salmonellosis, to the Director of the Public Health Laboratory Service.

All 52 Public Health Laboratories and about 300 hospital laboratories in England, Wales and Ireland contribute to this voluntary reporting system. Microbiologists are asked to send, each week, totals of positive identifications of salmonellas (amongst other organisms) identified in their laboratory, including the numbers of specific serotypes and phage types identified. Details of outbreaks are also requested and will include numbers of persons involved, place of outbreak, i.e. the place where the food was eaten, incubation times, suspected food vehicle and causative organism. The data are analysed weekly and summaries are currently included four-weekly in the Communicable Disease Report (CDR). Annual statistics are reported in the CDR and may also be published. Delays occur between date of specimen receipt by laboratory and date reported to CDSC and these delays may vary in time with the serotype identified (Appendix Figures 1c.i,ii).

Local authority reporting

A new scheme was introduced by CDSC in 1980, as part of a rationalisation of reporting of food poisoning, which enabled the MOEH or local Environmental Health Department to report directly outbreaks of food poisoning and salmonellosis (Anon, 1981a; Galbraith, 1985). The report form requested details about the numbers of persons affected and the types of illness, type and place of outbreak, suspect food and its preparation and storage and laboratory results following testing of human faeces or foods. It was intended that these reports would supplement information on outbreaks reported by laboratories and identify outbreaks not reported by laboratories, including those for which no aetiological agent was identified, and would also facilitate collection of data in a standard format. The adopted format was designed to meet requirements of the WHO Surveillance Programme for Control of Foodborne Infections and Intoxications in Europe (WHO, 1981).

Other data sources

Data from death certificates are recorded in the local death register by the registrar of births, deaths and marriages of that district. Each week copies of death entries are forwarded to OPCS for analysis. However, until recently only the first cause of death was coded and food poisoning was only rarely recorded as the cause of death; salmonella infection (other than **S. typhi** or **S. paratyphi**) was more frequently recorded as an underlying cause of death.

Other data sources based on clinical reporting by general practitioners (GPs) or reasons for admission to, or discharge from, hospital are available but are of little practical value in surveillance of salmonellosis. Either information is too non-specific, data is limited by sample size or publication of data is subject to long delay.

Figure 1c.i

Mean interval between week of specimen receipt by laboratory and week report received at CDSC

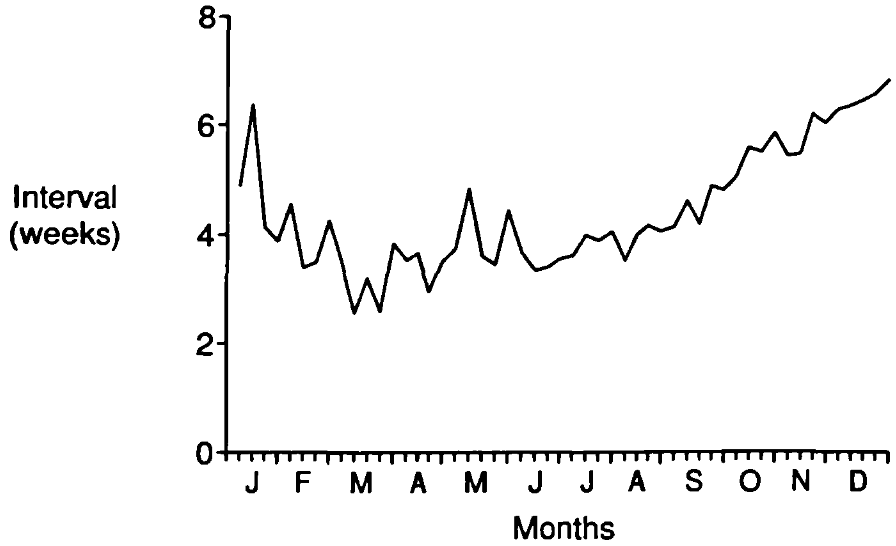
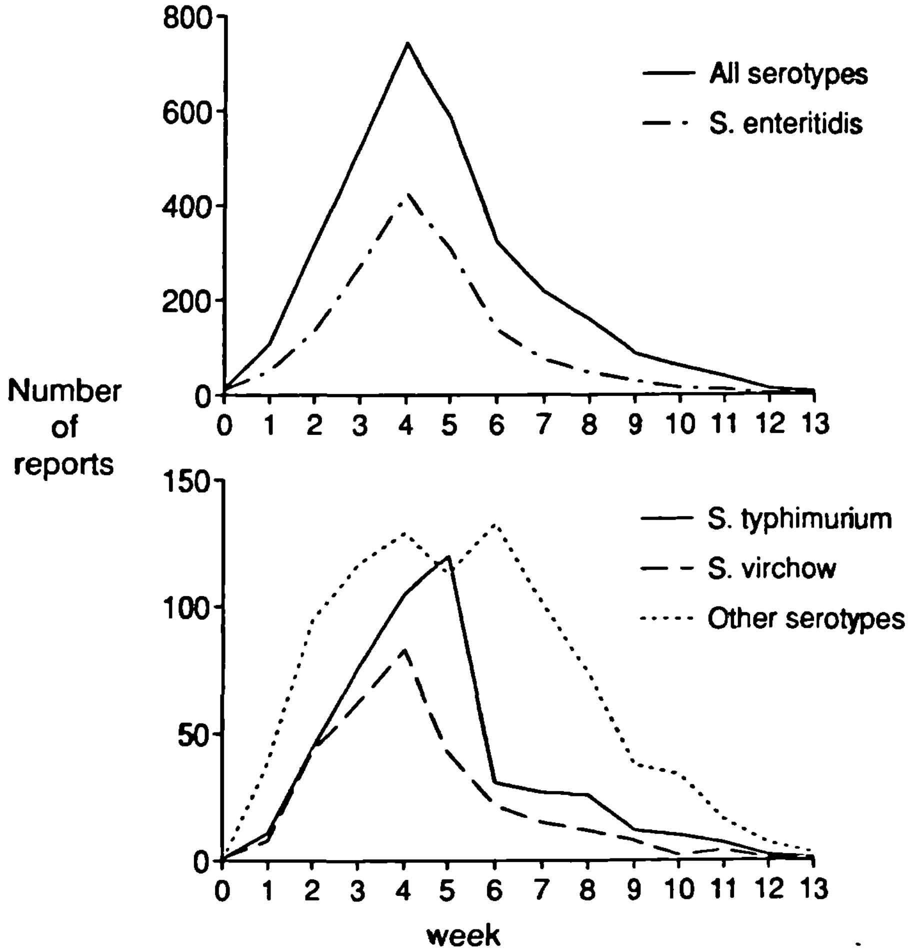


Figure 1c.ii

Interval between receipt of specimen in laboratory and week report received by CDSC, for selected serotypes



Source: Laboratory reports to CDSC, England and Wales 1989

Appendix 2a

INTEREST IN ECONOMIC EVALUATION IN THE HEALTH SECTOR

There appear to be two main reasons why, at least in the UK, there has been a resurgence of interest in economic evaluation in the health sector. First, the inefficiency and inequity of resource use and distribution by medical professionals was challenged in the 1970s and led to a more critical evaluation of medical practice; indeed the fundamental role of medicine was challenged in the 1970s by the suggestion that social and economic factors, not advances in medical care, were the main reasons for changes in patterns of morbidity and mortality (Cochrane, 1972; Abel-Smith 1976; McKeown 1979). Secondly, concerns about rapidly rising costs of treatment and care have coincided with a political ideology which has sought to restrain public expenditure and encourage critical evaluation of resource needs. The resulting pressures on resources have led to an emphasis on the need to evaluate both the efficacy and efficiency of public sector activities (J Roberts, 1989).

Thus the need for economic appraisal of disease costs and the benefits of preventive measures is now well established. An increasingly large number of studies relating to economic appraisal within the health sector are to be found in the literature. Most fall largely into three broad categories covering management and organisation, diagnosis and treatment, and prevention. Economic evaluation is providing valuable information for justification, targeting and decision-making in the health sector, particularly where this relates to decision-making about alternatives, in strategy or procedure (Gellman, 1971; Atkinson and Townsend, 1977; Cantor et al, 1985; Altman et al, 1987; Williams, 1985; Hibbard et al, 1985; Gudnadottir, 1985). However, although a third of 163 studies of economic appraisals by Drummond (1981) could be described as relating to public health, including 28 concerned with infectious diseases, none were related to foodborne illness.

Summary of Costs Associated with Eleven Salmonella Outbreaks in Food Service Establishments in the United States, Canada and the Netherlands

Type of establishment/ function	Date	Country	Etiologic agent	Number ill	Total costs	Average total costs/case
Restaurant	1973	USA	Salmonella	26	$ 57,423	$ 456
Restaurant	1979	USA	Salmonella	50	$122,019	$2,440
Hotel	1982	Canada	Salmonella	137	$108,656	$ 749
College	1982	Canada	Salmonella	55	$ 69,311	$ 788
Hospital	1963	USA	Salmonella	1,000	$699,400	$ 699
Hospital	1981	N Ireland	Salmonella	116	$ 57,784	$ 498
Hospital	1982	Canada	Salmonella	196	$480,310	$2,451
OP home*	1981	Canada	Salmonella	>51	$ 95,487	$1,836
OP home*	1983	Canada	Salmonella	115	$522,981	$4,548
Banquet	1962	USA	Salmonella	700	$158,881	$ 227
Conference	1981	Netherlands	Salmonella	700	$399,755	$ 571

* Old persons' home

Source: Mann et al (1983); Todd (1985); Beckers et al (1985)

Tangible Costs Associated with Seven Salmonella Outbreaks Reported in the United Kingdom since 1981

Year	Serotype (number of cases)	Food	Public Sector Cost (£)	Society Cost (£)	Total (£)
1981	S. typhimurium (654)	Raw milk	43,493	39,737	83,230
1982*	S. napoli (245)	Chocolate	104,312	274,646	378,958
1982	S. typhimurium (31)	Not known	3,234	3,280	6,514
1985*†	S. ealing (76)	Milk powder	163,012	14,500,000	14,663,012
1985	S. thompson/ infantis (242)	Turkey	34,612	79,240	113,852
1987	S. heidelberg (19)	Poultry	23,146	2,197	25,343
1987	S. typhimurium (19)	Raw milk	11,392	>6,500	>17,892

* outbreaks due to manufactured foods

† direct costs only

Source: Cohen et al, 1983; Neilson, 1984; Anon, 1985; Yule et al, 1988; Barnass et al, 1989; Roberts et al, 1989; Sockett, unpublished data

Summary of Costs Associated with Human Salmonellosis in Germany in 1977 (in Deutschmarks)

Cost categories	Reported cases Cost (DM)	Estimated additional cases Cost (DM)	Total cost (DM)	%	Average cost per case (DM)
Tangible Direct:					
medical costs	7,002,155	6,260,985	13,263,140	12	35
examination costs	6,291,767	-	6,291,767	6	16
Tangible Indirect:					
welfare costs	3,147,760	21,133,849	24,281,609	23	63
loss of consumption	5,178,960	12,081,356	17,260,316	16	45
Intangible:					
loss of leisure	13,238,018	32,664,313	45,902,331	42	120
Other costs:	1,150,880	-	1,150,880	1	3
Total	36,009,540	72,140,503	108,150,043	100	282

Source: Krug and Rehm (1983)

Table 2d.11

Summary of Costs Associated with Human Salmonellosis in Canada in 1977 (in Canadian dollars)

Cost categories	Type and number of cases				% of total cost
	Reported costs (1977 Canadian $)				
	Hospitalised (1,625)	Non-hospitalised (6,849)	Unreported (415,226)	Total (423,700)	
Hospital and medical cost	4,198,859	869,823	-	5,068,682	6
Investigation cost	76,375	321,903	-	398,278	1
Loss of productive output	456,450	806,964	27,470,533	28,733,947	34
Loss of leisure	674,251	1,215,925	45,573,432	47,463,608	57
Loss of life	1,986,194	-	-	1,986,194	2
Total	7,392,129	3,214,615	73,043,965	83,650,709	100
Average	4,549	469	176	197	

Source: Curtin (1984)

Appendix 3a

LISTS OF TABLES FROM WHICH DATA WAS EXTRACTED

Food poisoning notifications and death registrations (OPCS).

Information on notified food poisoning for England and Wales and death registrations due to "Other salmonella infections" (ICD 003) where salmonella infection was given as the underlying cause of death, and "Other food poisoning (bacterial)" (ICD 005) was extracted from Communicable Disease Statistics (OPCS and CDSC, 1980-1989). Analyses were based on data from tables listed below:

1a. Notifications of selected infectious diseases. England and Wales.
1b. Deaths from selected infectious diseases. England and Wales.
2. Weekly notifications of selected infectious diseases and deaths from selected causes. England and Wales.
3. Notification rates per 100,000 population for selected infectious diseases. Sex and age group. England and Wales.
4. Notifications of selected infectious diseases. Sex and age group. England and Wales, standard regions, regional health authorities.
5. Corrected notifications of selected infectious diseases. England and Wales, standard regions, regional health authorities, Greater London, London boroughs, metropolitan and non-metropolitan counties and districts, port health authorities.

Population.

Population statistics were extracted from Population Trends published quarterly by OPCS (OPCS, Spring 1988). These included estimates of the population of England and Wales and NHS Region, and estimates of population by age and sex. Tables from which data was extracted for analysis are listed below:

2. Population: national (estimates and projections), constituent countries of the United Kingdom.

4. Population: sub national, Health regions of England.
6. Population: age and sex, United Kingdom, Great Britain and constituent countries.

Salmonella infection in animals.

Details of salmonella infections in animals, by animal species, salmonella serotype and phage type was extracted from annual summaries 'Animal Salmonellosis' published by MAFF, Welsh Office Agriculture Department, Department of Agriculture and Fisheries for Scotland. The data presented were extracted from annual summaries covering the period 1976 to 1989 (MAFF, 1976-1989).

Under the Zoonoses orders (1975, 1989) an incident may relate to the finding of salmonellae in individual animals or groups of animals or their products or surroundings. The list of tables from which data was extracted is given below:

1. Cattle, sheep, pigs and poultry, Great Britain.
2. Cattle, including calves.
3. Calves, including cattle under 10 months of age.
4. Sheep.
5. Pigs.
6. Fowls.
7. Turkeys.
11. **S. typhimurium** phage types in cattle, including calves.
13. **S. typhimurium** phage types in sheep.
14. **S. typhimurium** phage types in pigs.
15. **S. typhimurium** phage types in poultry.
16. Contamination rates of domestic processed animal protein.
18. Contamination rates of imported processed animal protein.

Data on salmonella incidents in animals was collated by the Central Veterinary Laboratory prior to 1976 and published by Sojka and Field (1970) and Sojka et al (1977) (see Appendix 3b).

Travel statistics.

Details of numbers of visits abroad, by destination, by persons travelling from the UK was extracted from the Employment Gazette published by the DoE (DoE, 1990; personal communication). The table from which data was extracted is listed below:

8.6. Overseas travel and tourism, visits abroad by country visited.

Statistics on consumption of meat and other protein food.

Statistics relating to the consumption of meat and other protein foods, and consumer expenditure on meat products were supplied by the MLC or extracted from the MLC publication Meat Demand Trends (MLC, 1991); the tables from which data were extracted are listed below:

B2. Estimated consumer expenditure on meat and other protein foods at current prices.
C1. Estimated supplies of meat in the United Kingdom.

Data on meat retailing patterns and ownership of fridges and freezers were extracted from specific articles in Meat Demand Trends which are referenced in the text.

Weather.

Monthly and annual ambient temperature for England and Wales for the period 1960 to 1989 were obtained from the Climatological Department of the London Weather Centre, 284, High Holborn, London WC1V 7HX.

Appendix 3b

INCIDENTS RECORDED IN ANIMALS, 1960-1975

The two most notable trends during this period were a marked peak in incidents recorded in cattle in 1969 and a decline in incidents recorded in poultry following a peak in reports in 1960. Throughout the period the number of incidents recorded in both sheep and pigs remained stable and low. The serotypes most commonly reported in sheep were **S. abortusovis**, **S. dublin** and **S. typhimurium** whilst those in pigs were **S. cholerasuis**, **S. dublin** and **S. typhimurium**.

In cattle, two serotypes, **S. dublin** and **S. typhimurium** were responsible for the majority of incidents. However, an increase in cattle which began in the early 1960's was largely due to an epidemic of **S. dublin** infection which peaked at 4,498 incidents in 1969 (Sojka et al, 1977). The subsequent decline in **S. dublin** in cattle was probably related to the introduction of a vaccine for calves and a succession of years of low prevalence of liver-fluke infection which was related to **S. dublin** infection in cattle. Over the same period there was a lesser but steady increase in incidents of **S. typhimurium** infection in cattle.

Incidents in poultry declined after reaching a peak in 1960 of 2,695 incidents which were mainly attributed to two poultry specific types, **S. gallinarum** and **S. pullorum**. Incidents due to these serotypes declined following the introduction of blood testing under the Poultry

The Stock Improvement Plan which enabled infected flocks to be identified and culled (Sojka et al, 1977) and improvements in husbandry practices. While incidents due to these poultry specific types were declining there was an increase in reports due to both **S. typhimurium** (49% of incidents, 1974) and **S. enteritidis** (13% of incidents, 1973). A number of other serotypes were also commonly associated with poultry including **S. agona**, **S. thompson**, **S. menston**, **S. senftenberg**, **S. montevideo**, **S. livingstone**, **S. indiana**, **S. heidelberg**, **S. virchow**, **S. derby**, **S. stanley** and **S. 4,12:d:-**.

Laboratory reports of salmonella infection: England and Wales 1989
Month of specimen received by laboratory
and month reported to CDSC

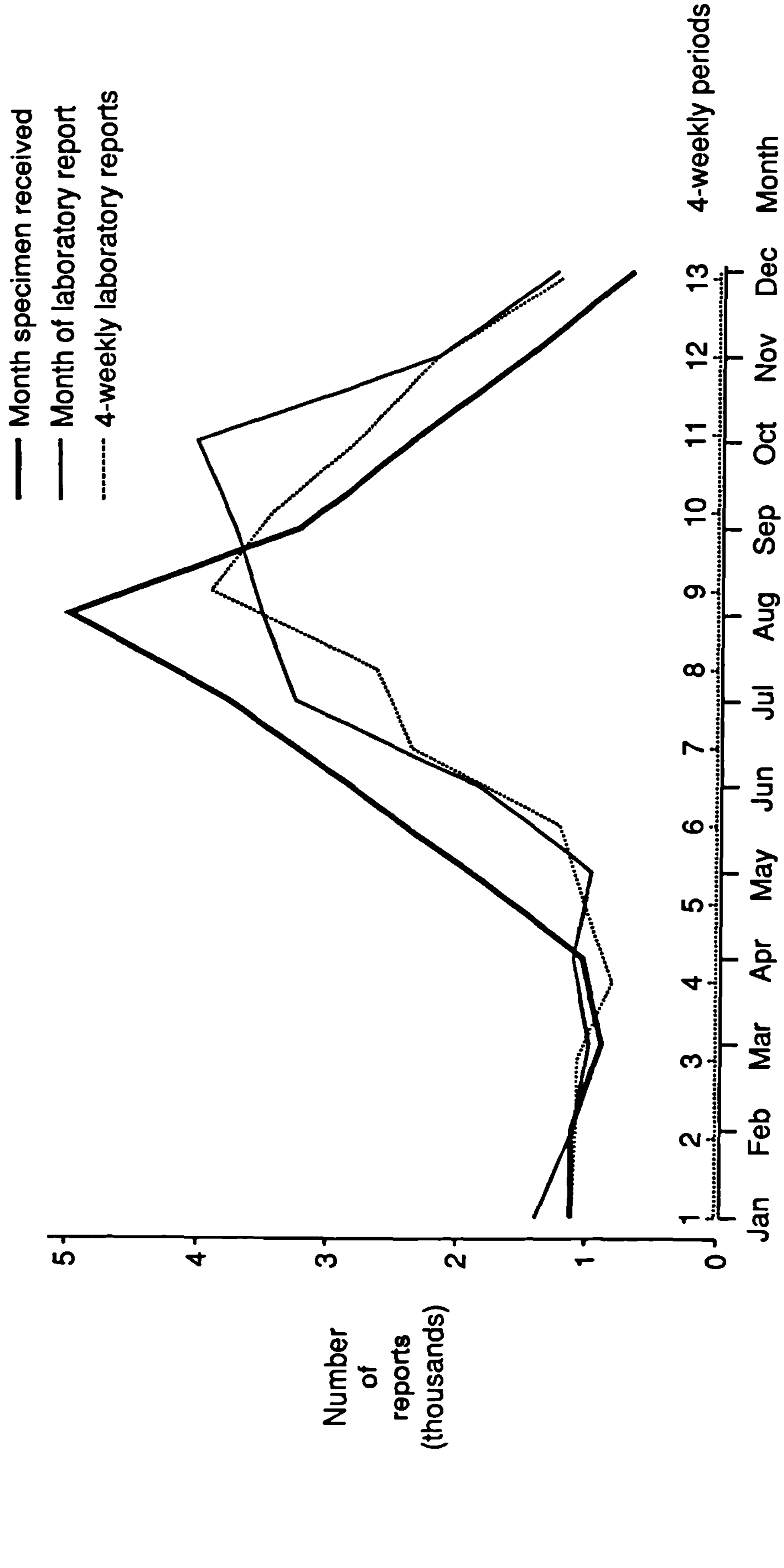
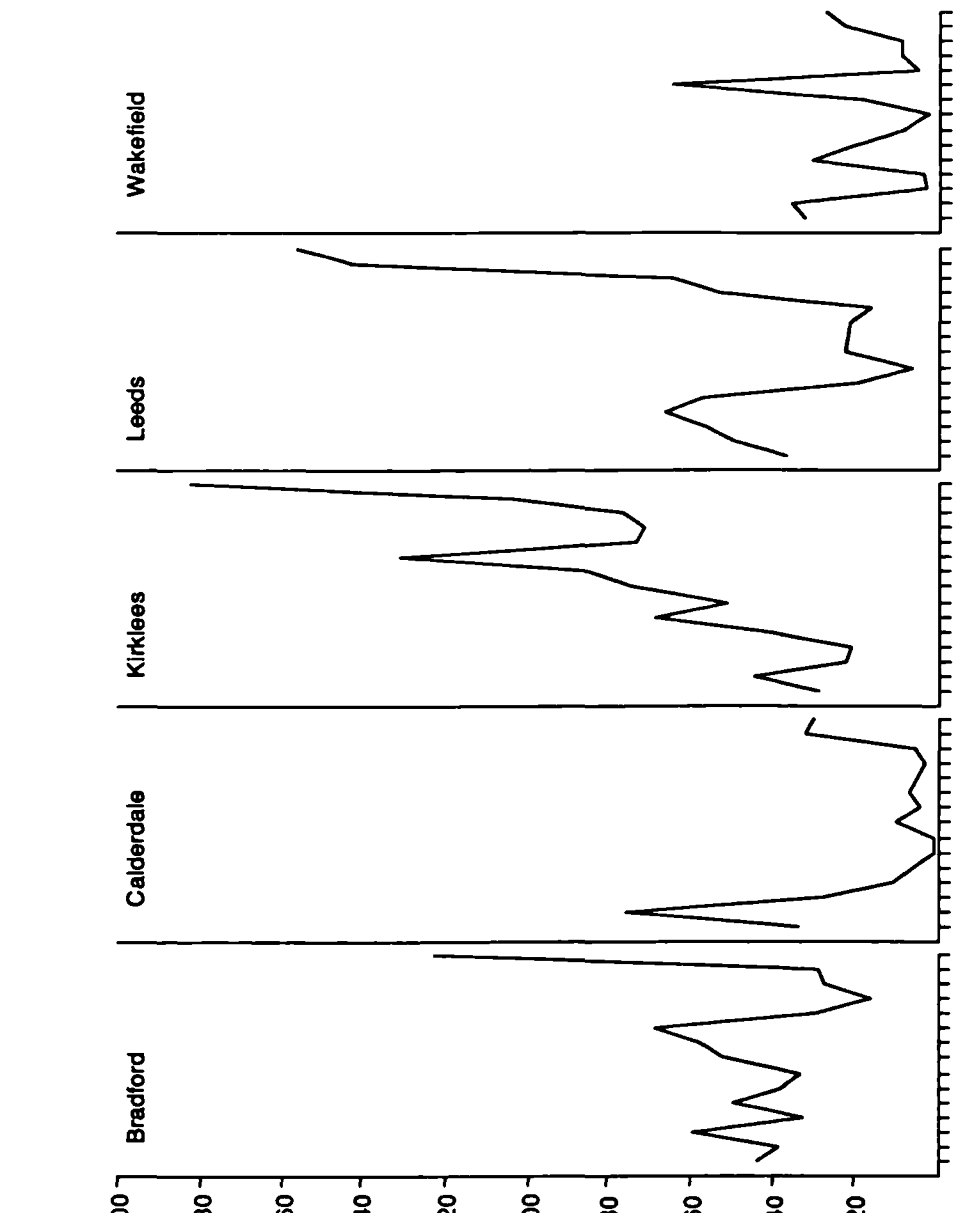
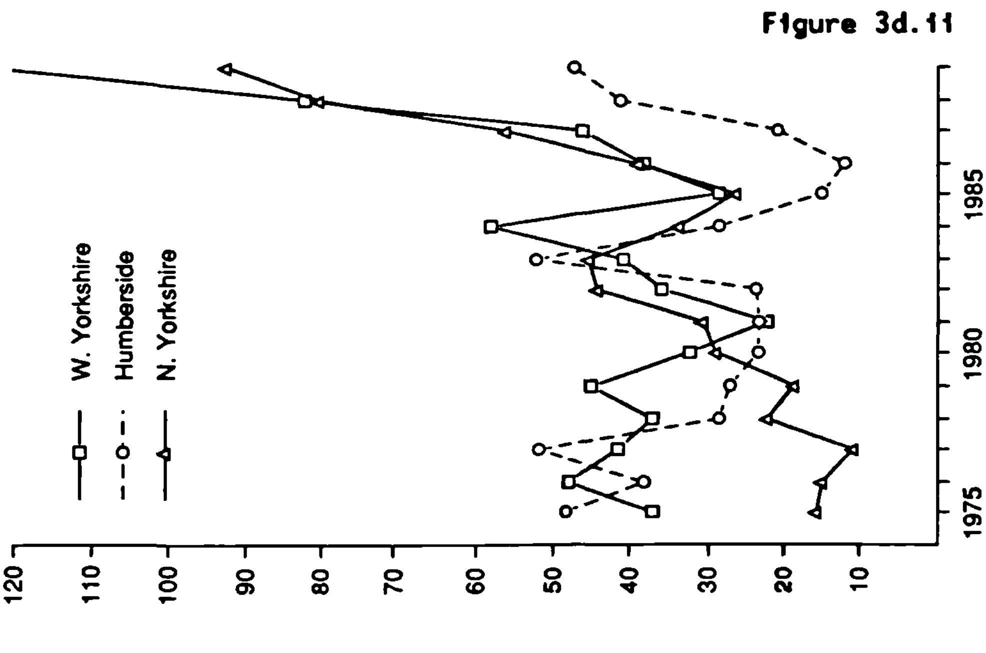


Figure 3d.i



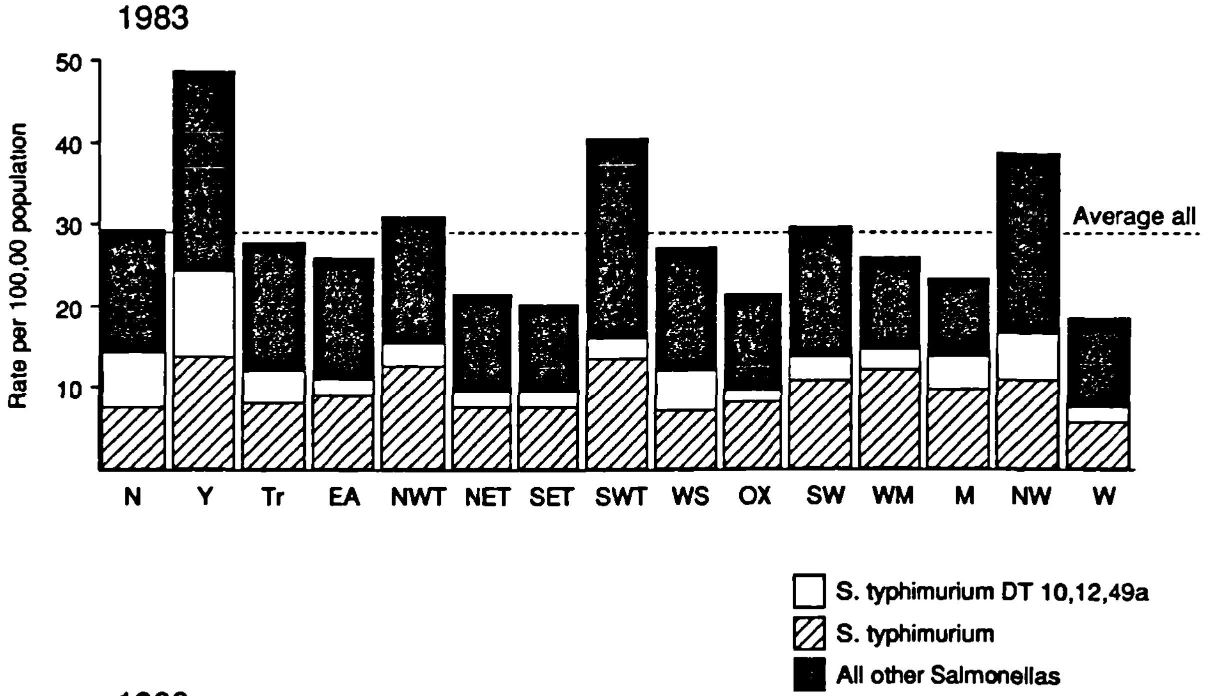
Food poisoning notifications (formally notified) by district:
West Yorkshire 1975-1989
Notification rate per 100,000 population

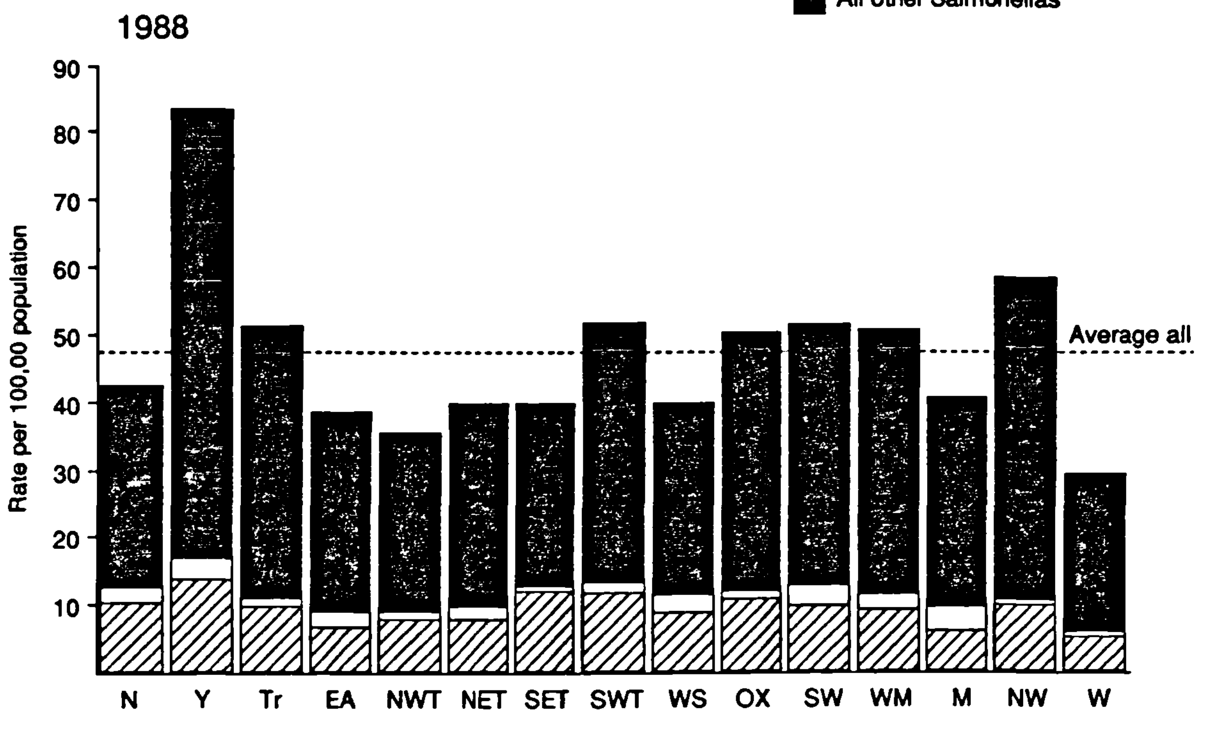
Figure 3d.ii



Food poisoning notifications (formally notified) by county: Yorkshire Region 1975-1989
Notification rate per 100,000 population

Salmonella isolation rates per 100,000 population
Comparison by RHA





Appendix 3f

ANALYSIS OF "OTHER" NON FAECAL SALMONELLA ISOLATIONS

Extraintestinal isolations of salmonellas reported in England and Wales for the period 1975 to 1989 are presented in Table 3f.i. This shows total isolations, by serotype, for those serotypes accounting for >1% of isolations from blood and "other" sites, and >10% of CSF isolates, and the rate (per 1,000 reports) for each serotype.

A detailed analysis of 434 other infections was made for the period 1975 to 1983; 211 in males and 205 in females (18 sex not stated) (Dr S. Young, CDSC, unpublished). Bone-joint and biliary tract infections accounted for over half of the reports in infants whereas no respiratory tract or cardiovascular infections were recorded in this age group (Table 3f.ii), but were increasingly common with age in adult age groups.

Only two serotypes, **S.choler-suis** and **S. dublin** were markedly above the average, indicating that between a half and a third of reported infections respectively developed serious complications. Ten other of the serotypes listed were above the average (16.9 per 1,000 reports) and the remainder were below this. This latter group included **S. typhimurium** and **S. enteritidis**.

Reports of Extra-Intestinal Isolations of Salmonella : England and Wales 1975-1989

Total Reports and Rate per 1,000 Reports for Each Serotype (in brackets)

Serotype	Total isolates	Site of isolation: Blood*		CSF†		Other*		Total	
S. agona	4,958	27	(5.45)	1	(0.20)	10	(2.02)	38	(7.66)
S. cholerae-suis	52	27	(519.23)	2	(38.46)	-		29	(557.69)
S. dublin	552	114	(206.52)	1	(1.81)	14	(25.36)	129	(233.70)
S. enteritidis	47,006	604	(12.85)	11	(0.23)	88	(1.87)	703	(14.96)
S. hadar	10,966	54	(4.92)	-		17	(1.55)	71	(6.47)
S. heidelberg	5,299	121	(22.83)	4	(0.75)	26	(4.91)	151	(28.50)
S. kedougou	1,211	28	(23.12)	3	(2.48)	11	(9.08)	42	(34.68)
S. newport	3,314	49	(14.79)	1	(0.30)	25	(7.54)	75	(22.63)
S. panama	2,253	68	(30.18)	3	(1.33)	21	(9.32)	92	(40.83)
S. saint-paul	2,838	32	(11.28)	2	(0.70)	8	(2.82)	42	(14.80)
S. stanley	2,637	45	(17.06)	1	(0.38)	5	(1.90)	51	(19.34)
S. typhimurium	64,874	672	(10.36)	6	(0.09)	119	(1.83)	797	(12.29)
S. virchow	12,835	406	(31.63)	14	(1.09)	61	(4.75)	481	(37.48)
S. bredeney	2,145	18	(8.39)	7	(3.26)	7	(3.26)	32	(14.92)
S. anatum	1,751	10	(5.71)	-		6	(3.43)	16	(9.14)
S. brandenburg	633	21	(33.18)	-		8	(12.64)	29	(45.81)
S. derby	1,268	9	(7.10)	1	(0.78)	9	(7.09)	19	(14.98)
S. give	853	14	(16.41)	-		7	(8.21)	21	(24.62)
S. indiana	2,579	22	(8.53)	1	(0.39)	13	(5.04)	36	(13.96)
S. infantis	3,139	19	(6.05)	1	(0.32)	7	(2.23)	27	(8.60)
S. montevideo	2,703	22	(8.14)	-		13	(4.81)	35	(12.95)
S. muenchen	675	3	(4.44)	-		7	(10.37)	10	(14.81)
S. oranienburg	545	9	(16.51)	1	(1.83)	6	(11.01)	16	(29.36)
S. san-diego	269	10	(37.17)	1	(3.72)	6	(22.30)	17	(63.20)
Total	175,355	2,404	(13.71)	61	(0.35)	494	(2.82)	2,959	(16.82)
Other serotypes#	14,516	185	(12.74)	5	(0.34)	60	(4.13)	250	(17.22)
Total all serotypes	189,871	2,589	(13.64)	66	(0.35)	554	(2.92)	3,209	(16.90)

* serotypes accounting for ≥1% of blood or "other" isolates over the period

† serotypes accounting for ≥10% of CSF isolates over the period

77 other serotypes were recorded

<u>Other Serious Infections : 1975-1983</u>

Age of Case and Type of Infection

Site of infection	Age group (years)							Total
	<1	1-4	5-14	15-44	45-64	≥65	Not stated	
Bone/joint	4	5	15	21	11	17	1	74
Genito-urinary	8	3	6	35	25	42	9	128
Biliary tract	2	-	-	25	19	21	7	74
Respiratory tract	-	-	2	6	22	20	2	42
Cardiovascular	-	-	-	7	8	30	1	48
Intra-abdominal	1	1	3	11	9	3	1	29
Other*	4	1	2	10	7	14	2	39
Total	19	10	28	115	101	147	23	434

* extra-abdominal abscesses, skin infections, parotid infection and conjunctivitis

Source: Dr S Young, Communicable Disease Surveillance Centre (unpublished data)

Appendix 3g

SALMONELLA SEROTYPES RECORDED IN THE ANNUAL TOP TEN: 1962 - 1989

Serotypes fell into three groups according to the frequency with which they were recorded (Table 3g.i). First, **S. typhimurium** and **S. enteritidis** which were recorded every year in the period under review. Over this period **S. typhimurium** was the most common serotype recorded in every year up to 1988. **S. enteritidis** was in the top six serotypes every year during this period, was consistently the second most common type from 1983 and in 1988 replaced **S. typhimurium** as the most commonly reported serotype.

Second, 13 serotypes were frequently recorded in the top ten and usually occupied the middle rank order. These included **S.heidelberg**, **S. virchow**, **S. newport** and **S. infantis**, recorded in at least half of the years in the period. All serotypes in this group were recorded in the top ten for one or more periods of at least three consecutive years. The third group consisted of serotypes only occasionally in the top ten; nine were recorded once and six twice. The annual numbers of identifications reported for many of these serotypes was often less than 150, and reporting may have been affected by a single outbreak.

Serotypes in the Ten Most Commonly Reported Salmonellas in Any Year

England and Wales ; 1962-1989

Serotype	No. of times in top ten	Median annual rank	When in top ten ≥3 successive years
S. typhimurium	28	1	1962-89
S. enteritidis	28	3	1962-89
S. heidelberg	22	5	1962-66, 1969-72, 1974-81, 1986-89
S. virchow	20	3	1967-70, 1976-89
S. newport	18	7	1973-78, 1980-84, 1986-89
S. infantis	18	8	1969-72, 1980-89
S. hadar	15	4	1975-89
S. stanley	14	5	1965-70, 1983-87
S. indiana	14	7	1967-70, 1973-79
S. agona	14	4/5	1970-80
S. panama	12	5/6	1965-73
S. bredeney	11	7/8	1969-73
S. saint-paul	10	6/7	1971-73, 1978-83
S. anatum	9	7	1964-67
S. montevideo	9	6	1980-85
S. brandenburg	6	3	
S. thompson	3	7	
S. derby	3	9	
S. muenchen	3	10	
S. dublin	3	8	1967-69
S. menston	2	8/9	
S. reading	2	9/10	
S. oranienburg	2	6/7	
S. give	2	8/10	
S. senftenberg	2	2/4	
S. braenderup	2	8/10	
S. onderstepoort	1	8	
S. glostrup	1	10	
S. chester	1	7	
S. takoradi	1	10	
S. haifa	1	8	
S. ibadan	1	10	
S. napoli	1	10	
S. gold-coast	1	10	
S. kedougou	1	7	

Appendix 3h

DETAILS OF MAJOR SEROTYPES REPORTED

Salmonella typhimurium

The species S. **typhimurium** is comprised of a large number of strains which can be distinguished by their susceptibility to bacteriophages (phage types; designated: **DT**). The proportion of reported isolations which were phage typed increased over the period from 1981 from 71% to over 80%. About 230 phage types have been recognised and between 89 and 115 different types were recorded by CDSC in each year since 1981. However, only 19 types were recorded in the annual top ten and only two types **DT12** and **DT49** were recorded each year (Appendix Table 3h.i).

The five most frequently reported types consistently accounted for about half of the typed strains reported each year, although no strain was particularly dominant (Appendix Figure 3e.i). There may also have been regional variation in the frequency of reporting of different phage types. Thus, **DT12** which was the most commonly reported type from 1981 to 1984 and in 1989 was most often associated with the north of England particularly Northern, Yorkshire, Mersey and North Western Regions. This phage type was associated with poultry, pork, other meat products and raw milk in outbreaks reported to CDSC between 1980 and 1989

Data on the S. **typhimurium** phage types (definitive types, **DT**) associated with incidents in cattle, sheep, pigs and poultry were examined for the period 1980 to 1989 (Table 3h.i,ii). The ten most commonly reported phage types accounted for the majority of strains typed for each animal species considered. The proportion in cattle due to the ten commonest types was 87% but the remaining typed incidents were due to a wider variety of other recognised phage types (excluding RDNC strains) than for other animal species. A high proportion of incidents in sheep and pigs were also due to the most common phage types. In poultry the proportion was lower (67%).

Salmonella enteritidis

Two peaks in reporting of this serotype are evident from the trend shown in Figure 3.6; the first, a small peak, in the late 1960's and a second, current increase which started in the early 1980's. However, the rate of increase rose dramatically from 1985.

A phage typing scheme for **S. enteritidis** was introduced in 1981 and CDSC routinely kept data on phage types from 1985. The number of types reported annually doubled between 1985 and 1987. Of the 50 phage types currently recognised (L. Ward, Division of Enteric Pathogens, CPHL, personal communication) 15 have occurred in the annual top ten over the period 1985 to date. However, a very different pattern has emerged when compared with **S. typhimurium**. First, the top five types in any year have accounted for over 90% of reports of typed strains. Second, one type, **PT4**, has accounted for an increasing proportion of reports, rising from 65% in 1985 to 87% in 1990 (Appendix Figure 3h.1).

Other major serotypes

Prior to 1967 **S. virchow** was unusual in this country. However, a peak in reporting was recorded in 1969 and a second increase in the late 1970's was followed by a steady rise in annual totals (Figure 3.6).

Human infection with **S. agona** was first reported in 1969 (Figure 3.6). The numbers of cases recorded increased rapidly during the early 1970's and in 1975 it was the second most commonly reported serotype. Between 1977 and 1980 **S. hadar** was the second most common serotype reported (Figure 3.6). **S. panama** peaked in 1970 (Figure 3.6). **S. anatum** peaked later in 1975 (Figure 3.6). Two peaks in reporting of **S. heidelberg** were recorded in 1969 and again in 1975, the same year that **S. saint paul** reports also peaked (Figure 3.6).

Salmonella Typhimurium Phage Types Occurring in the Annual, Ten Most Commonly Reported Types

Rank Order and Percentage Proportion* of S. typhimurium Reports : England and Wales 1981-1989

Phage type†	1981		1982		1983		1984		1985		1986		1987		1988		1989	
12 [1,2,3]	1	(12)	1	(18)	1	(15)	1	(14)	3	(9)	3	(7)	5	(6)	2	(11)	1	(14)
49 [1,2,3,4]	8	(4)	5	(6)	5	(7)	17	(5)	1	(13)	1	(15)	1	(18)	1	(14)	3	(8)
170 [1,2,3]	6	(6)	2	(9)	4	(7)	5	(6)	9	(4)	4	(6)	-		-		-	
49a [1,2]	-		3	(8)	3	(7)	6	(6)	-		6	(6)	6	(5)	-		9	(3)
104 [1,2,4]	5	(7)	6	(6)	6	(6)	8	(5)	6	(5)	-		4	(7)	4	(6)	6	(5)
110 [1,2,3]	-		-		8	(4)	4	(8)	8	(4)	8	(5)	7	(4)	8	(4)	-	
10	2	(11)	4	(8)	2	(12)	3	(9)	2	(10)	-		-		6	(6)	10	(3)
204 [1,2,3,4]	7	(6)	7	(4)	7	(5)	10	(4)	5	(6)	5	(6)	-		9	(3)	8	(3)
193 [1,3]	10	(3)	9	(4)	10	(4)	-		7	(4)	7	(5)	3	(7)	3	(8)	2	(13)
141	-		-		-		2	(9)	4	(6)	2	(8)	2	(8)	5	(6)	-	
U285	-		-		9	(4)	9	(5)	-		-		-		-		-	
204c [1,2,3]	-		-		-		-		10	(4)	10	(4)	-		10	(3)	-	
9	-		-		-		-		-		9	(5)	8	(4)	-		-	
204a [1,2,3]	4	(8)	8	(4)	-		-		-		-		-		-		-	
18	9	(3)	10	(2)	-		-		-		-		-		-		-	
108	-		-		-		-		-		-		-		-		4	(8)
66	-		-		-		-		-		-		9	(4)	7	(5)	7	(4)
208	-		-		-		-		-		-		10	(4)	-		5	(6)
12a	3	(11)	-		-		-		-		-		-		-		-	

* (percentage proportion figures in brackets)

† phage types in the ten most commonly reported types in cattle[1], sheep[2], pigs[3], and poultry[4]

Table 3h.11

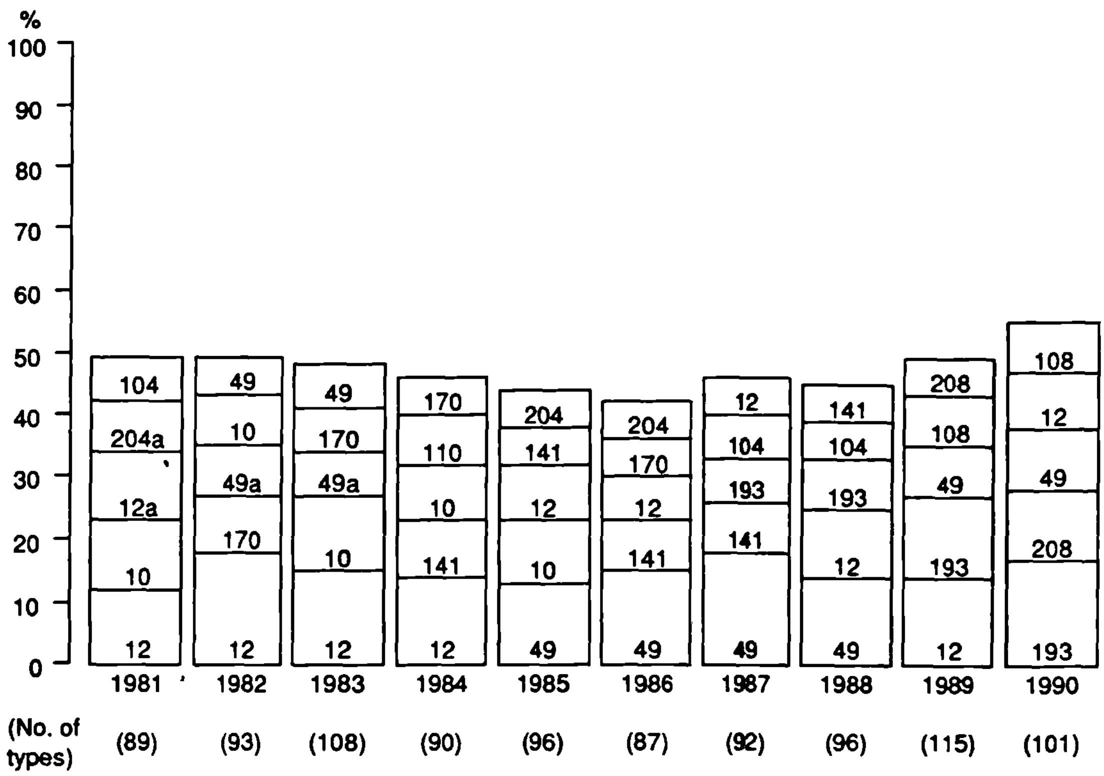
The Ten Most Commonly Reported Phage Types of Salmonella Typhimurium in Animals : England and Wales 1980-1989

Cattle		Sheep		Pigs		Poultry	
Phage type*	Per cent of total	Phage type*	Per cent of total	Phage type*	Per cent of total	Phage type*	Per cent of total
204c	43	204c	27	12	21	49	19
204	10	12	10	193	15	8	9
204a	8	204	8	204c	10	99	9
49	6	104	7	208	6	141	6
12	5	204a	7	170	5	40	6
104	4	49	6	204	4	9	4
193	4	170	5	49	3	104	4
170	3	110	3	40	3	204	4
49a	2	49a	3	110	3	10	3
110	2	141	3	12a	3	160	3
				18	3		
				204a	3		
	87%		79%		79%		67%

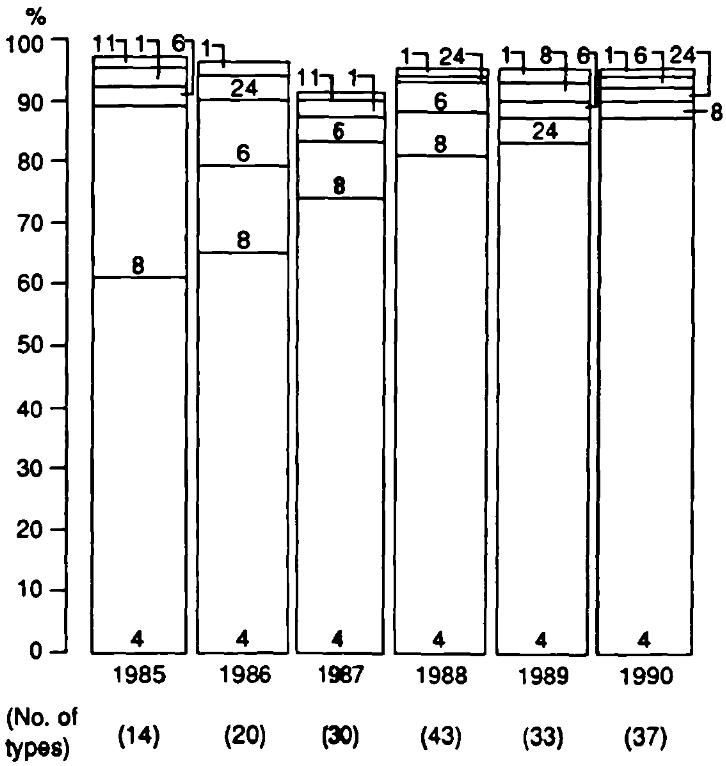
* Numbers of phage types recognised (excluding RDNC types):
cattle 97; sheep 46; pigs 41; poultry 66

Proportion of S. typhimurium and S. enteritidis reports due to the most common phage types reported each year.
England and Wales

S. typhimurium phage types (top 5 by year)



S. enteritidis phage types (top 5 by year)



Appendix 31

FOODS IMPLICATED IN OUTBREAKS DUE TO MANUFACTURED FOODS

Outbreaks associated with manufactured foods are summarised in Table 31.1. Most (132) were of salmonella infection, of which cooked and processed meats were the most significant category. In addition to cold cooked meats and pies there were three salmonella outbreaks associated with pate including two where the product was imported from Belgium (1) and France (1). Two other outbreaks implicated imported foods, one due to chopped ham from Denmark and one due to salami sticks imported from Germany (Cowden et al, 1989a).Two outbreaks were associated with eating processed fish and shellfish. A further 6 outbreaks were associated with canned foods including 5 implicating canned meat and 1 implicating canned crab.

Six salmonella outbreaks were associated with milk and dairy products. In two pasteurised milk caused cases community-wide, however, it was likely in these outbreaks that either the heat process itself was inadequate or the milk was contaminated post pasteurisation. Cheese was associated with illness in 3 outbreaks; one due to goat milk cheese from Turkey, a second implicating a UK manufactured cheese made with raw milk and a third associated with a soft cheese from Ireland also made with raw milk. The remaining outbreak was due to contaminated infant milk formula in 1985 in which the association between illness and consumption of the particular dried milk product was confirmed epidemiologically and microbiologically (Rowe et al, 1987).

Seven salmonella outbreaks were associated with eating bakery products. In five, cakes filled with reconstituted cream/custard fillings were implicated. The other two were associated with doughnuts and lemon meringue pie. This last outbreak was due to **S. enteritidis PT4** and may have resulted from the use of contaminated shell-egg in the meringue topping.

Powdered foods, other than milk powder, were implicated in two salmonella outbreaks. The first was associated with contaminated custard powder and the second was due to nationally distributed savory corn snacks containing autolysed yeast based powdered flavouring

(Joseph et al, 1991).

The remaining two outbreaks did not fit any specific food category and included a salmonella outbreaks due to contaminated orange juice used in a canteen and a widespread outbreak in the community in 1982 due to contaminated chocolate bars imported from Italy (Gill et al, 1983). This outbreak was particularly interesting because of the low numbers of contaminating organisms found in the bars. Reports from Italy indicated that there had been a similar outbreak in northern Italy concurrent with the outbreak in the UK and that **S. napoli** had been isolated from bore-hole water in Italy that year (S Salmaso, Institut de Superiore de Sanita, Rome, personal communication). Contamination may have resulted from seepage from the outer water jacket pipe into the inner chocolate-carrying pipe via a hair line crack.

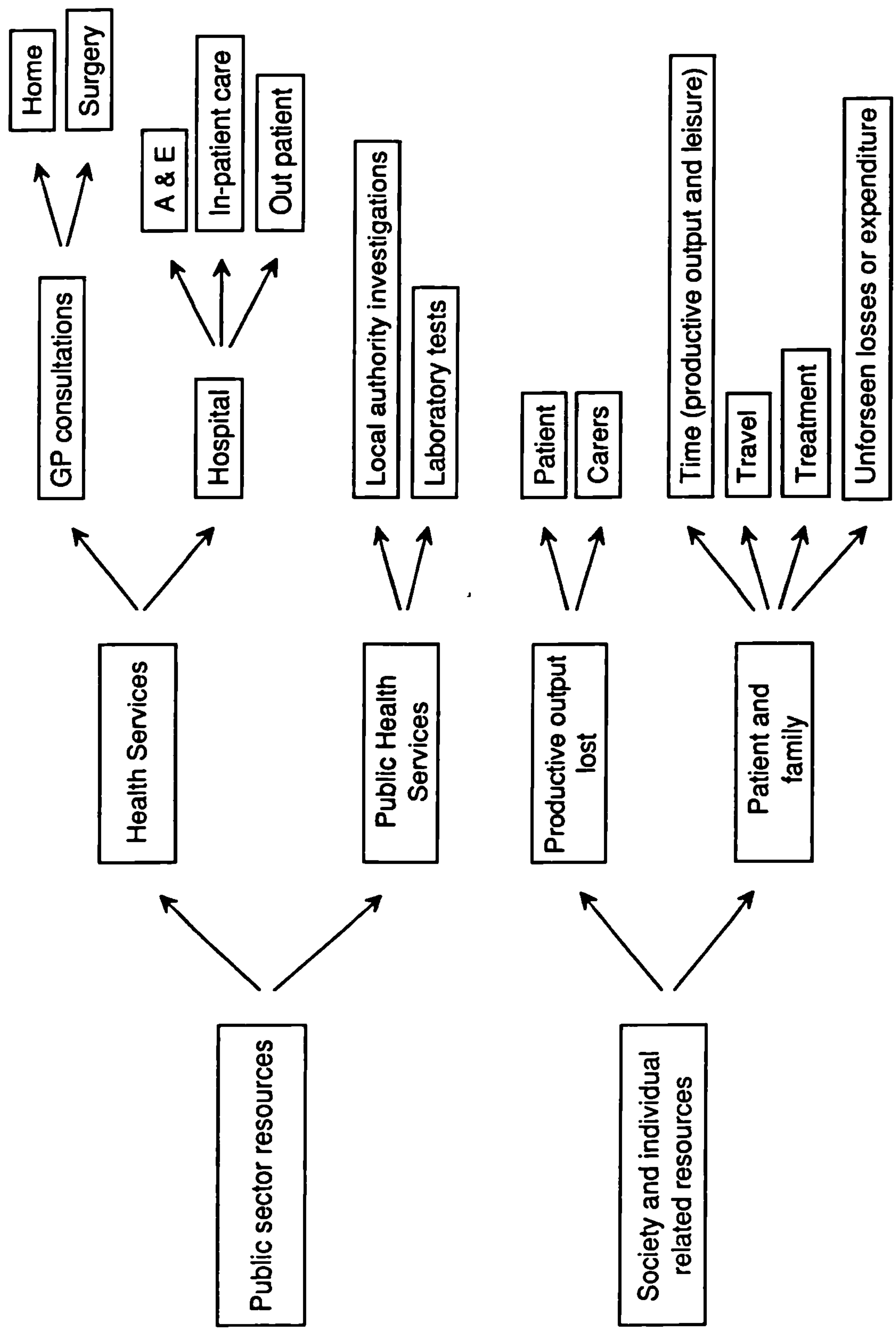
Outbreaks Associated with Manufactured Foods*

England and Wales : 1980-1989

Type of food	Cause of outbreak: Salmonella		Cause of outbreak: Other or unknown		Total	
Cooked foods, processed meats and meat pies; potted meats, pâté	107	(4)	42	(2)	149	(6)
Processed fish and shellfish	2		33	(2)	35	(2)
Canned foods:						
meats	5		10	(4)	15	(4)
fish and shellfish	1		51	(47)	52	(47)
vegetables	-		1	(1)	1	(1)
Dairy products	6	(2)	14	(1)	20	(3)
Bakery products	7		5		12	
Powdered foods	2		1		3	
Other	2	(1)	5	(1)	7	(2)
Total	132	(7)	162	(58)	294	(65)

* imported products shown in brackets

The Main Areas of Cost Related to Salmonella Infection



Appendix 4b

SURVEY TO IDENTIFY AND EVALUATE COSTS ASSOCIATED WITH SALMONELLA INFECTION

Objectives

To evaluate the impact of human salmonella infection on health care services and environmental health services by measuring time and resources expended in the care and investigation of individual cases. Costs to the individual affected and to society in general will be based on estimations of lost productivity of cases and illness-related expenditure. A copy of the questionnaire is attached.

Methods

The survey will be conducted in England and Wales in the autumn of 1988 by means of a two-part questionnaire which is described below. An introductory letter about the survey and a sample questionnaire will be sent to the Medical Officer for Environmental Health for each district, and the collaboration of environmental health departments in distributing the questionnaire to individuals with proven salmonella infection will be sought. Numbers of questionnaires distributed in each local authority district will be varied according to the size of the population in that district. It is hoped that the total number of cases surveyed will represent about a 5-10% sample of all reports for the year. Each questionnaire will be accompanied by a covering letter explaining the purpose of the study and requesting the help of the case by prompt completion and return.

Questionnaire : Part A

This section is to be completed by the investigating officer (usually an Environmental Health Officer) and includes details of the patient's name and address, numbers of specimens sent for microbiological examination and resources and time spent on the investigation. On completion, this section is to be returned as soon as possible to CDSC, on its own, and will be linked to Part B by a common serial number.

Questionnaire : Part B

Investigating officers will be asked to deliver a Part B questionnaire to each patient on the adjudged last follow-up visit. This section is to be completed by the infected individual or, if this person is a child or handicapped, by a parent, guardian or responsible adult. Details asked examine the severity of illness, use of health care services and costs to the patient and his/her household. When completed, the questionnaire is to be returned directly to CDSC using a pre-paid addressed envelope.

Non-responders

Non-responders will be identified by the return of Part A without a subsequent return of Part B within the next two weeks. Non-responders will receive up to two follow-up letters, with questionnaires.

Questionnaire analysis

All questionnaires will be entered onto computer at CDSC and verified by double entry. Individual information will be treated in the strictest confidence and analysed data will be presented in a general format only. The results of the study will be submitted to recognised medical and scientific journals for publication.

FOOD POISONING COST SURVEY

These questionnaires (Parts A and B) are part of a national study to evaluate the economic costs of salmonella infection. The investigation consists of two questionnaires:

Part A (overleaf) is designed to identify the costs associated with the follow-up of confirmed cases of salmonella infection by Environmental Health Departments. This section should be filled in by the investigating officer when investigation of the case is near completion. Part A should be returned separately, as soon as possible, to CDSC using the pre-paid envelope supplied.

Part B (attached) examines the costs to the affected individual which result from a salmonella infection. It should be passed to the person being investigated on the last follow-up visit by the EHO. Part B is designed to be completed by the infected person, however, where there are likely to be language difficulties the EHO may wish to offer help in completing the questionnaire.

Please ensure that Parts A and B relate to the same salmonella positive individual. The study number on the top of part A and part B of each questionnaire is identical so the data can be easily collated at CDSC. All the information given on both questionnaires will be treated in strictest medical confidence and the analysis will be presented in general terms only.

Thank you once again for you help in this study and if you have any questions please do not hesitate to contact Paul Sockett by telephone on 01-200 6868 extension 4411.

IN CONFIDENCE

STUDY NUMBER | | | | |

A

ENVIRONMENTAL HEALTH DEPARTMENT INVESTIGATIONS

1. Name and address of person to whom part B was given: ....
....
....
....

2. Name of investigating officer ....

3. Address of Environmental Health Department ....
....
....

Please turn over

4. Please list below the salary grades of all staff involved in investigating the person named in 1. above, and estimate the time devoted to these investigations:

	Salary Grade	Days (and half days) spent on this investigation
a.	....	....
b.	....	....
c.	....	....
d.	....	....

5. Please estimate the following costs incurred by your department as a result of this investigation:

Travel (interview, laboratory visits etc) £ ....

Administration (photocopying, postage, telephone calls etc) £ ....

Salary paid to persons barred from work £ ....

Other (describe) .... £ ....

6. How many specimens were submitted for laboratory studies?

		Number tested	Number positive
a.	Stool specimens from 1. above	☐☐	☐☐
b.	Stool specimens from contacts	☐☐	☐☐
c.	Food specimens	☐☐	☐☐
d.	Environmental swabs/specimens	☐☐	☐☐

7. Type of salmonella identified if known: Salmonella ....

8. Was the person named in 1. ☑
   a. Sporadic (not associated with others) ☐ → Go to end
   b. Family outbreak ☐
   c. General outbreak ☐

9. Where did the outbreak take place? ....
....

10. When did it take place? ....

11. How many persons were known to be ill? ☐☐☐☐

Thank you for completing this questionnaire. Please return it as soon as possible, using the pre-paid, addressed envelope.

IN CONFIDENCE STUDY NUMBER [| | |]

B

FOOD POISONING COST-ANALYSIS QUESTIONNAIRE

This questionnaire is designed to find out how much you (the patient) and your family were affected by your recent salmonella infection. Your illness may have upset you and your family's normal daily routine and could have had a financial impact also. In this study we are trying to find out how large or small these effects are.

The questionnaire should be filled in by the person who was ill. If the patient is unable to do so (because the patient was a child or handicapped) a responsible adult should complete it on their behalf.

Please answer every section. Questions should be answered by putting a tick (✓) in the appropriate box(es) or by writing on the dotted lines.

Please read each question fully before you answer it

Please do not write in the margin

When you have finished the questionnaire please return it, as soon as possible, in the pre-paid reply envelope.

THE INFORMATION YOU GIVE WILL BE TREATED IN STRICT CONFIDENCE, WILL NOT BE PASSED TO ANYONE ELSE WITHOUT YOUR PERMISSION AND WILL BE KEPT SECURE

Please write your name and address in the space below:

PLEASE GO TO SECTION 1

SECTION 1 THIS SECTION ASKS FOR SOME BASIC INFORMATION ABOUT YOU OR THE PERSON WHO WAS ILL IF YOU ARE COMPLETING THE QUESTIONNAIRE ON THEIR BEHALF

1. What is the date today? day ..../ month ..../ year 19....

2. When were you born? day ..../ month ..../ year 19....

3. When did your salmonella illness start? day ..../ month ..../ year 19....

4. Are you (that is the person with salmonella)? male ☐ 1 or female ☐ 2

5. Are you (that is the person with salmonella) (tick a box)

a:
- Pre-school child ☐ 1
- School child ☐ 2
- Student at university/college ☐ 3
- Housewife ☐ 4
- Retired ☐ 5
- Unemployed ☐ 6
- Employed - full time ☐ 7
- Employed - part-time ☐ 8

} If either box ticked

6. What is your current job? ....

7. How many people, including yourself, normally live in your household? ...... people

8. Please list the other members of your household below (tick those who had a similar illness within 2 weeks of your illness)

Relationship to you	Sex: ring Male or Female (1 / 2)		Age (years)	Occupation (job)	Had a similar illness
eg Husband	(M)	F	26	Car mechanic	✓
	M	F			
	M	F			
	M	F			
	M	F			
	M	F			
	M	F			
	M	F			
	M	F			
	M	F			
	M	F			

PLEASE GO TO SECTION 2

SECTION 2 THE QUESTIONS IN THIS SECTION ARE TO FIND OUT HOW YOUR ILLNESS AFFECTED YOU. PLEASE ATTEMPT EVERY QUESTION.

1. Because of your illness how many days were you: (write in as many boxes as you need; if none write 0)

Confined to bed in hospital?	☐☐ days
In hospital but able to get up?	☐☐
Confined to bed at home?	☐☐
At home but able to get up?	☐☐
Feeling ill but able to go to school work, shops etc?	☐☐
Only slightly unwell but otherwise not affected?	☐☐

☐☐☐

2. How many days paid employment (full or part-time) did you miss? ☐☐ days

3. Show which of the following symptoms you had by ticking a box to indicate how mild or severe that symptom was:

(tick a box for each symptom)	None	Mild	Fairly severe	Severe
Diarrhoea	☐ 0	☐ 1	☐ 2	☐ 3
Fever (shivering/sweating)	☐ 0	☐ 1	☐ 2	☐ 3
Muscle aches/pains	☐ 0	☐ 1	☐ 2	☐ 3
Nausea (feeling sick)	☐ 0	☐ 1	☐ 2	☐ 3
Stomach pains	☐ 0	☐ 1	☐ 2	☐ 3
Vomiting (being sick)	☐ 0	☐ 1	☐ 2	☐ 3
Wind/belching	☐ 0	☐ 1	☐ 2	☐ 3
Other	☐ 0	☐ 1	☐ 2	☐ 3

If 'Other' please describe ....

4. Please list the occupation of any person who took time off paid full or part-time employment because of your illness, do not include visits to doctor or hospital:

Relationship to you	Occupation	Days off paid employment

NOW GO TO SECTION 3

SECTION 3 DID YOU SEE YOUR DOCTOR (GP)? Yes [ ]1 No [ ]2 → go to Section 4

1. Did your GP visit you at home? Yes [ ] No [ ]

How many times? .... times

2. Did you see your doctor at his surgery? Yes [ ] No [ ]

How many times? .... times

3. How many visits did you make to deliver specimens to the surgery?

.... visits

4. How many visits to the surgery (to see doctor or deliver specimens) were by:
(counting home to surgery or surgery to home as one journey each)

Public transport	[ ]	journeys
Cab/taxi	[ ]	
Private car	[ ]	
Walk	[ ]	
Other	[ ]	

If other, please describe: ....

5. How far, in miles, do you live from the doctors surgery? .... miles

6. How long, in hours, did your visits to the doctor usually take? .... hours

7. Did someone go with you to the doctor? Yes [ ] No [ ] → go to question 10

How many times? .... times

8. What is that persons occupation? .... [ ][ ]

9. What is that persons relationship to you? (eg wife etc.) .... [ ]

10. Did you receive medicines on prescription for this illness?

Yes [ ] No [ ] → go to Section 4

How many items altogether? .... items

11. Are you exempt from prescription charges (under 16, retired, pregnant etc.)?

Yes [ ]1 No [ ]2

GO TO SECTION 4

SECTION 4 AS A RESULT OF THIS ILLNESS DID YOU GO TO AN HOSPITAL ACCIDENT & EMERGENCY (CASUALTY) DEPARTMENT?

Yes [ ]1 No [ ]2 → go to Section 5

1. How many times? .... times

2. How long, in total, (in hours) did you spend in casualty? .... hours

3. Did someone go with you to casualty? Yes [ ]1 No [ ]2 → go to Section 5

4. What is that persons occupation? ....

5. What is that persons relationship to you? eg wife etc. ....

GO TO SECTION 5

SECTION 5 WERE YOU ADMITTED TO HOSPITAL? Yes [ ]1 No [ ]2 → go to Section 6

1. How many days were you in hospital? ......days

2. On average, how many visitors did you have each day? ......visitors

3. While in hospital how much do you think you spent on:

   Clothes (ie night clothes), toilet articles £ ....

   Newspapers, books, telephone calls £ ....

   Food, sweets, juice etc? £ ....

   Other £ ....

   If other please specify: ....

4. If the patient was a child, did an adult stay in hospital with the child?

Yes [ ]1 No [ ]2 → go to Section 6

What is the occupation of the accompanying adult (state if housewife, unemployed, retired): ....

GO TO SECTION 6

SECTION 6 DID YOU ATTEND AN HOSPITAL OUTPATIENT DEPARTMENT?

Yes [ ]1 No [ ]2 → go to Section 7

1. How many times did you go to outpatients? .... times

2. How long, in hours, on average did each visit take? ....hours
(from leaving home to returning home)

3. Did someone go with you to outpatients? Yes [ ]1 No [ ]2 → go to question 6

4. What is that persons occupation? (state if housewife etc) ....

5. What is that persons relationship to you: (eg wife) ....

6. On average, how much did you (and accompanying person) spend on food/drink for each visit £...............

GO TO SECTION 7

SECTION 7 IF YOU ATTENDED CASUALTY, OUTPATIENTS OR WERE ADMITTED TO HOSPITAL, COMPLETE THIS SECTION. IF NOT GO TO SECTION 8

1. About how far, in miles, is your home from the hospital? .... miles

2. How many journeys did you make by the following? (count home to hospital or hospital to home each as one journey)

Ambulance	[ ]	journeys
Public transport	[ ]	
Cab/taxi	[ ]	
Private car	[ ]	
Walk	[ ]	
Other	[ ]	

If other please specify: ....

GO TO SECTION 8

SECTION 8 DID YOU BECOME ILL WHILE ON HOLIDAY? Yes ☐1 No ☐2 → go to Section 9

1. Were you on holiday in? (tick a box) UK ☐ Abroad ☐

If abroad, which country? .... ☐☐

2. Which resort(s) did you visit? ....

3. How long (in days) was your holiday? .... days

4. How many days of your holiday were you? (answer each question)

   a) Confined to bed? ☐☐ days

   b) Up - but unable to leave hotel? ☐☐

   c) Able to get about but feeling unwell? ☐☐

5. About how many days, in total, did other family members or friends spend looking after you?

   .... days

6. How much did you spend on medicines/medical care? £ ....

7. Did you have to stay longer because of illness? Yes ☐1 No ☐2 → go to question 9

8. How much extra did this cost you? £ ....

9. Did you claim back illness costs on insurance? Yes ☐1 No ☐2

10. Please give details and amounts of any other costs relating to your illness while on holiday (eg telephone calls)

....

.... ☐☐☐☐

PLEASE GO TO SECTION 9

SECTION 9 OTHER EXPENDITURE DUE TO ILLNESS

1. How much did you spend on over the counter remedies for this illness? (not while on holiday)

   £ ....

2. How much did you spend on telephone calls which resulted from your illness? (not while on holiday)

   £ ....

3. Please describe any other costs which you feel resulted from your illness:

	ITEM	APPROXIMATE COST
1.	....	£ ....
2.	....	£ ....
3.	....	£ ....
4.	....	£ ....
5.	....	£ ....
6.	....	£ ....

PLEASE GO TO SECTION 10

SECTION 10 SALARY DETAILS

In order to calculate accurately the financial impact of your illness it is necessary to ask for details of your (the affected persons) income. Would you therefore indicate your income below. This information will be treated in strictest confidence. If, however you are unable to disclose this information this is understood and I would like to express my thanks for the time taken to complete the questionnaire and for your help with this study.

What is the monthly take home pay, to the nearest £50, of the person who was ill?

£ ....

THIS INFORMATION IS FOR MEDICAL COSTINGS ONLY AND WILL BE TREATED AS STRICTLY CONFIDENTIAL

Thank you again for completing this questionnaire. Please return it as soon as possible, using the pre-paid envelope, to:

Communicable Disease Surveillance Centre
61 Colindale Avenue
London NW9 5EQ

Appendix 4c

PILOT STUDY OF SALMONELLA COSTING QUESTIONNAIRE
Patient Response to Questionnaire

Introduction

In December 1987 and January 1988, 101 people in England were infected with **Salmonella typhimurium** DT 124. Epidemiological investigations quickly identified a German salami stick as the vehicle of infection and microbiological investigations confirmed the presence of the organism in the product (Cowden et al, 1989a).

A questionnaire was available which had been developed from previous costing studies. This outbreak presented an ideal opportunity to pilot the questionnaire, which was designed to evaluate patient-related costs and health care costs, for use in a survey to evaluate national costs resulting from salmonella infection. This was to be self-completed by the infected person, specifically to test the individual's understanding of the questions and the acceptability of the questionnaire.

Questionnaire Assessment

Description of the questionnaire

Each questionnaire had a unique identifying study number on the front introductory page, which also had a brief description of the purpose of the study and instructions relating to completion of the questionnaire. A covering letter to introduce the questionnaire was also sent. The questionnaire was divided into 10 sections which are itemised below (Table 1).

A pre-paid reply envelope was supplied with each questionnaire and individuals were asked to return completed forms as soon as possible. A telephone number at CDSC was given in the covering letter so that any enquiries regarding the questionnaire could be answered as quickly as possible.

Table 1 Sections Included in Cost Questionnaire

Section	Information Requested
1	Details of infected individual and composition of household
2	Length and severity of illness
3	Use of family doctor (GP) services
4	Use of casualty services
5	Details relating to admission to hospital
6	Details of out-patient visits
7	Details of travel to and from hospital
8	Costs due to infection acquired abroad or on holiday
9	Other expenditure resulting from illness
10	Salary details of infected individual

Response rate

The questionnaires were sent by post to 72 primary household cases on 8 July, 1988. A total of 48 (67%) were returned within three weeks. To improve the response rate a letter encouraging compliance and a duplicate questionnaire were sent to all non-responders on 1 August, 1988. A further 10 completed questionnaires were returned by 24 August. This increased the number returned to 58, a final response rate of 81%. In addition two blank questionnaires were returned and were excluded from the analysis. A summary of the response to individual questions is given in Table 2.

Response to each section/question

Section I

This section asked for details of the affected individual's age, sex, occupation and household composition. Only one conditional question was included: Question 6 asked for the current occupation if the answer to Question 5 was "full- or part-time employed". Most people answered all questions in this section and only two persons failed to give a specific date for onset of illness (Question 3), but one of these was included: Question 6 asked for the current occupation if the answer

Table 2 <u>Response to Questions</u>

Question number		Number responding*	Question number		Number responding*
Section I	1	57	**Section IV**	1	57
	2	58		2	8/8
	3	56		3	8/8
	4	57		4	6/7
	5	58		5	7/7
	6	5/6			
	7	58	**Section V**	1	57
	8	57		2	10/10
				3	7/10
				4	9/9
Section II	1	58			
	2	6/6	**Section VI**	1	56
	3	58		2	5/5
	4	48		3	4/5
				4	4/5
				5	4/5
Section III	1	55		6	4/5
	2	55			
	3	49/50	**Section VII**	1	14/15
	4	55/56		2	15/15
	5	48/50			
	6	49/51	**Section VIII**		57
	7	44/46			
	8	45/46	**Section IX**		56
	9	57			
	10	43/44	**Section X**		6/6

* Number who answered each question out of a possible 58 unless otherwise given; e.g. for conditional questions x/y shows number of answers/number to whom question applied.

to Question 5 was "full- or part-time employed". Most people answered all questions in this section and only two persons failed to give a specific date for onset of illness (Question 3), but one of these provided this item of data elsewhere on the form. Only one of six persons to whom Question 6 was applicable did not answer but again supplied the relevant data elsewhere on the form. Answers to Questions 1 and 3 showed that the time interval between onset of illness and completing the questionnaire was between six and eight months (median seven months).

Section II

This section asked for details of length of illness and a subjective impression of the severity of symptoms. All those individuals to whom the questions were relevant answered them. One question gave the respondents the opportunity to give a subjective assessment of the discomfort resulting from their illness by saying how much they would have paid to avoid being ill. Although 48 persons answered the question, 24 of these ticked the "Don't know" box. The poor response may have been due to a misunderstanding of the question by some persons and the difficulty of assessing discomfort in monetary terms. It was therefore felt this question should be amended in future development of the questionnaire.

Section III

This section examined the use of GP services and the prescription of medicines. Three conditional questions were included. If the respondent visited a GP's surgery (Question 2) they were asked for details of travel and time for that visit (Questions 3-8). If the person was accompanied on the visit (Question 7), details of that person's occupation and relationship to the patient were requested (Questions 8-9). If a prescription was provided (Question 9) the patient was asked if he/she was exempt from charges.

In general questions in this section had a good response. Only three persons failed to answer conditional Question 2 and each of the remaining questions in this section was answered by all but one or two persons.

Section IV

This section asked for details of visits to hospital casualty departments. Question 1 was conditional and if the answer was "yes" then the section should be completed. Question 3 was conditional on being accompanied by another person; if "yes", then Questions 4 and 5 should be answered. Eight persons visited casualty departments and all answered the relevant questions.

Section V

This section requested details of any individual who was admitted to hospital and associated costs, and completion of this section was conditional on a "yes" reply to Question 1. Ten admissions to hospital were recorded and all completed this section; however, three patients gave no indication of whether or not they spent money in hospital (Question 3).

Section VI

This section requested details relating to out-patient visits to hospital, including number and length of visits, whether or not accompanied and expenditure on food or drink. Five persons went to out-patient departments and all but one of these individuals gave the information requested.

Section VII

This section applied only to patients who had used hospital services. This totalled 15 persons. All answered the question about method of travel and 14 answered the question about distance from home to hospital.

Section VIII

This section examined costs relating to infection acquired whilst on holiday. Completion of this section was conditional on a "yes" to the question "Did you become ill while on holiday?" at the beginning of the section. All but one person replied. Two people became ill whilst on holiday in the United Kingdom and both completed the questionnaire.

Section IX

This section gave the respondent the opportunity to describe additional costs of illness not already mentioned. Only two respondents failed to answer at least one of the three questions in this section. However, several persons described additional categories without estimating the associated costs. One additional cost in particular was mentioned by a number of respondents. This was the time taken off paid employment by relatives and friends to look after the families of the infected individual, especially if a parent accompanied a child to hospital. Other costs mentioned included lost play-group or school fees and increased expenditure on cleaning materials and disinfectants. Some intangible costs, such as general discomfort and dislocation of family life, were also commented on.

Section X

This section asked for details of the gross monthly income of the infected person. All six persons in paid employment who returned questionnaires answered this question.

Conclusions

The proportion of persons returning the questionnaire (81%) and the overall response to the questions was very encouraging, considering both the subject of the survey and the lapsed period between illness and form completion. Only one question (Question 4 in Section II) caused particular concern. The low response to this question implied that it was poorly understood, and this suggested that an alternative approach, aimed at obtaining a detailed description of the number and severity of symptoms, should be explored.

Distribution of Questionnaires by National Health Service Region

Region	Population (millions) (% of population of England and Wales)	Number of local authorities in Region	Authorities promising to participate: Number (% of Region's population)	Authorities promising to participate: Number returning questionnaires (% of Region's population involved)	Number of questionnaires returned (% of those sent)
Northern	3.08 (6.2)	28	10 (32)	8 (26)	48 (3.2)
Yorkshire	3.60 (7.2)	22	19 (87)	16 (82)	173 (11.7)
Trent	4.63 (9.2)	39	29 (81)	23 (70)	163 (11.0)
E Anglia	1.99 (4.0)	20	10 (47)	8 (37)	49 (3.3)
NW Thames	3.49 (7.0)	24	14 (52)	12 (45)	116 (7.8)
NE Thames	3.76 (7.5)	26	12 (49)	11 (44)	87 (5.9)
SE Thames	3.62 (7.2)	27	19 (69)	17 (64)	116 (7.8)
SW Thames	2.97 (5.9)	24	19 (91)	18 (89)	126 (8.5)
Wessex	2.88 (5.8)	28	11 (44)	10 (40)	58 (3.9)
Oxford	2.48 (5.0)	23	13 (52)	12 (48)	92 (6.2)
S Western	3.18 (6.3)	32	12 (40)	10 (36)	68 (4.6)
W Midlands	5.18 (10.3)	36	20 (60)	19 (59)	132 (8.9)
Mersey	2.41 (4.8)	13	7 (60)	7 (60)	91 (6.1)
N Western	3.99 (8.0)	24	11 (49)	9 (45)	88 (5.9)
Wales	2.82 (5.6)	38	25 (53)	20 (47)	75 (5.1)

Table 4e.i

Proportion of Errors and Omissions in a Random 10% Sample (150) of Survey Questionnaires

Questionnaire	Total possible entries	Errors	Omissions
Part A			
Coded questions	741	1 (0.1%)	-
EHO entries	1,238	17 (1.4%)	15 (1.2%)
Part B			
Coded questions	1,046	14 (1.3%)	6 (0.6%)
Patient entries	7,342	94 (1.3%)	511 (7.0%)

Table 4e.ii

Questions Most Frequently Associated with Errors

Type of question	Number of errors	
Part A		
Days investigation	6	
Local authority costs	8	
Laboratory results	2	
Type of outbreak	1	
Region	1	(coding error)
Part B		
Study number	1	(coding error)
Personal details	3	
Household details	22	(coding errors: 4)
Length of illness	17	(coding errors: 4)
Time off work	6	
Symptoms	10	
GP treatment	25	
Hospital treatment	13	(coding errors: 2)
Illness abroad	7	(coding errors: 1)
Costs to family	4	(coding errors: 2)
Total	126	(coding errors: 15)

Salary Scales for Environmental Health Officers (EHOs)
and Value of Time Spent on Investigations

Salary scale			Annual salary (£)	Daily pay (£)	Days of investigation	Value of time (£)
	1		3,957	16.77	8.00	134.16
	2		4,223	17.89	1.90	33.99
	3		4,563	19.33	0.60	11.60
	4		4,837	20.50	7.00	143.50
	5		5,177	21.94	7.80	171.13
	6	SC1	5,492	23.27	13.30	309.49
	7					
	8					
Clerical	9					
and	10					
Admin.	11	SC2	6,945	29.43	27.60	812.27
	12		7,126	30.19	0.50	15.10
	13		7,338	31.09	0.20	6.22
	14					
	15	SC3	7,645	32.39	42.40	1,373.34
	16					
	17		8,031	34.03	0.50	17.02
	18					
	19	SC4	8,519	36.10	7.50	270.75
	20		8,832	37.42	55.00	2,058.10
	21		9,161	38.82	8.50	329.97
	22		9,405	39.85	0.50	19.93
	23	SC5	9,685	41.04	116.80	4,793.47
Technical	24		10,006	42.40	0.80	33.92
	25		10,329	43.77	0.40	17.51
	26		10,664	45.19	1.00	45.19
	27	SC6	11,023	46.71	94.70	4,423.44
	28		11,390	48.26	0.25	12.07
	29		11,845	50.19	0.50	25.10
	30	SO1	12,243	51.89	209.90	10,891.71
Basic EHO	31		12,635	53.54	6.00	321.24
	32		13,008	55.12	0.15	8.27
	33	SO2	13,397	56.77	178.00	10,105.06
	34	PO1	13,784	58.41	88.00	5,140.00
	35		14,072	59.63	0.50	29.82
	36	PO2	14,450	61.23	15.00	918.45
	37		14,862	62.97	1.00	62.97
Senior EHO	38		15,303	64.84	0.50	32.42
	39	PO3	15,802	66.96	18.60	1,245.46
	40					
	41					
Principal	42	PO4	17,083	72.39	34.30	2,482.98
EHO	43		17,516	74.22	0.15	11.13
	44					
Senior		PO6	19,232	81.49	4.60	374.85
Principal						
EHO		PO8	22,043	93.40	8.00	747.20

Table 4g.i

Percentage of Value of Life within Age Bands and Degree of Association of Infection with Death

Association with death	Age group (years)					
	0-4	5-14	15-44	45-59	60-64	≥65
Caused	98	91	65	37	26	13
Contributed	49	45	33	19	13	7
Unrelated	1	1	1	1	1	1

Table 4g.ii

Proportionate Distribution of Deaths by Age at Death and Degree of Association of Infection with Death

Association with death	Age group (years)					
	0-4	5-14	15-44	45-59	60-64	≥65
Caused	1	1	3	4	4	47
Contributed	0.5	0.5	1	1	1	16
Unrelated	0.5	0.5	1	1	1	16

Correlation between Length of Illness and Use of Medical Services with Severity Index

Length of illness and type of service used*		Index group 1	2	3	4	5	6	r_s
n		19	105	290	509	192	114	
Length of illness	A	4.16	14.24	15.98	17.00	22.84	18.68	0.94
	N	13.17	17.18	16.73	17.96	23.33	19.19	0.89
	%	32	83	96	95	98	97	
Days off work	A	7.42	3.91	5.93	10.25	10.44	9.21	0.66
	N	17.63	11.11	13.76	22.00	20.67	21.88	0.66
	%	42	35	43	47	51	42	
Home consultations	A	0.21	0.41	0.77	1.05	1.45	1.28	0.94
	N	1.33	1.59	1.87	2.09	2.33	2.35	1.00
	%	16	26	41	50	63	54	
Surgery consultations	A	0.53	1.37	1.63	1.57	1.71	1.66	0.97
	N	1.43	2.06	2.17	2.20	2.73	2.39	0.94
	%	37	67	75	71	63	69	
Prescriptions	A	0.21	0.82	1.24	1.46	1.45	1.44	0.77
	N	2.00	1.04	1.99	2.17	2.26	2.08	0.66
	%	11	79	62	67	64	69	
Casualty visits	A	0	0.07	0.10	0.12	0.17	0.23	1.00
	N	0	1.17	1.47	1.19	1.22	1.37	0.66
	%	0	6	7	12	14	17	
Days in hospital	A	0.16	0.48	0.74	1.11	1.92	2.18	1.00
	N	3.00	8.33	6.11	6.21	6.59	6.53	0.37
	%	5	6	12	18	29	33	
Out-patients	A	0	0.12	0.07	0.13	0.22	0.33	0.94
	N	0	2.17	1.54	1.57	2.53	2.00	0.54
	%	0	6	4	8	9	17	

A = average for all cases in group;

N = average for number recording length of illness or use of a service;

% = proportion of N in group

* The averaged units presented in the columns, for each category listed, are, as appropriate: numbers of days, numbers of consultations, numbers of prescription items and numbers of visits.

Comparison of Age Distribution in Sample with Laboratory Reports and Population of England and Wales : 1988-1989

(percentages in brackets)

	Age group (years)							P
	<1	1-4	5-9	10-14	15-44	45-64	≥65	
Study: Total*	46 (3.8)	159† (13.2)	79 (6.6)	39† (3.2)	582 (48.3)	223 (18.5)	77 (6.3)	
Male	23	81	41	19	249	91	39	
Female	23	77	38	19	333	132	38	
Expected numbers:								
Laboratory reports	72 (6.1)	151 (12.5)	71 (5.9)	45 (3.7)	566 (47.0)	193 (16.0)	106 (8.8)	<0.001
								NS
								NS
Reports from DEP	54 (4.5)	181 (15.0)	83 (6.9)	48 (4.0)	562 (46.6)	177 (14.7)	100 (8.3)	<0.001
								NS
Population of England and Wales	17 (1.4)	65 (5.4)	154 (12.8)		552 (45.9)	261 (21.7)	154 (12.8)	<0.001
								NS
								NS

NS = not significant; * 24 whose age was not stated (10 male, 12 female, 2 sex also not stated); † 1 not stated

Expected values were calculated by applying the proportionate distribution by age in laboratory reports, reports to DEP and the population of England and Wales to the study sample.

Percentage Distribution of Use of Medical Services by Social Grouping*

Type of service	Social group I	II	IIIN	IIIM	IV	V
Admitted to hospital	17 (6.2)	14 (5.6)	15 (6.4)	20 (5.9)	18 (6.7)	19 (7.0)
Visited Casualty Department	7 (1.0)	6 (1.0)	10 (1.2)	13 (1.5)	10 (1.4)	15 (1.0)
Visited Out-patients Dept.	5 (1.8)	5 (1.4)	9 (2.7)	6 (1.9)	12 (1.2)	7 (5.5)
Home consultation	44 (1.6)	40 (2.1)	43 (2.1)	54 (2.1)	49 (2.0)	41 (2.1)
Surgery consultation	69 (2.0)	75 (2.2)	74 (2.7)	69 (2.2)	77 (2.6)	67 (3.1)
Received prescriptions	57 (2.0)	63 (2.1)	69 (2.0)	66 (2.4)	69 (2.0)	52 (1.8)

* Figures in brackets denote average use of services provided, i.e. days in hospital, attendance at Accident & Emergency and Out-patients Departments, GP consultations and prescription items dispensed.

The data presented shows the percentage distribution of use of services within each social group only and since individual cases may have used more than one type of service, neither rows nor columns will add up to 100%.

Table 4j.11

Proportionate Distribution of Use of Medical Services by Age Group*

Type of service	Age group (years)									
	0-4	5-9	10-14	15-24	25-34	35-44	45-54	55-59	60-64	≥65
Admitted to hospital	31 (5.0)	15 (3.5)	31 (5.2)	20 (6.8)	15 (6.5)	10 (6.4)	12 (8.2)	13 (9.2)	15 (6.6)	25 (9.5)
Visited Casualty Department	19 (1.3)	5 (1.0)	15 (1.5)	13 (1.4)	8 (1.2)	5 (1.3)	6 (1.5)	7 (1.0)	12 (1.5)	14 (1.0)
Visited Out-patients Dept.	7 (1.7)	5 (1.3)	15 (3.8)	4 (1.1)	9 (1.9)	7 (7.2)	9 (1.5)	4 (1.0)	9 (2.3)	16 (1.8)
Home consultation	50 (1.9)	35 (2.5)	49 (2.0)	49 (1.9)	31 (2.9)	49 (2.0)	49 (2.4)	48 (2.1)	62 (7.1)	57 (2.2)
Surgery consultation	73 (2.3)	58 (2.0)	69 (2.4)	75 (2.2)	72 (2.3)	77 (2.3)	70 (2.3)	61 (2.4)	65 (1.9)	50 (2.1)
Received prescriptions	53 (2.4)	51 (1.7)	56 (2.1)	67 (1.9)	67 (2.0)	69 (2.2)	74 (2.3)	76 (1.7)	82 (2.3)	55 (1.9)

* Figures in brackets denote average use of services provided, i.e. days in hospital, attendance at Accident & Emergency and Out-patients Departments, GP consultations and prescription items dispensed.

Appendix 4k

Table 4k.i

Ages of Cases Attending Accident and Emergency Departments

Age group	Number of cases (total visits in brackets): Admitted to hospital	Number of cases (total visits in brackets): Not admitted to hospital	Total
0- 4	26 (28)	12 (20)	38 (48)
5- 9	2 (2)	2 (2)	4 (4)
10-14	6 (9)	-	6 (9)
15-24	13 (14)	9 (16)	22 (30)
25-34	12 (14)	5 (6)	17 (20)
35-44	7 (10)	3 (3)	10 (13)
45-54	5 (5)	3 (7)	8 (12)
55-59	2 (2)	-	2 (2)
60-64	4 (3)	1 (2)	4 (6)
≥65	10 (10)	3 (3)	13 (13)
Total	86 (98)	38 (59)	124 (157)

Table 4k.ii

Frequency of Attendance at Out-Patients Departments for All Cases and Cases Admitted to Hospital

Number of visits	Number of cases (total visits in brackets): Admitted to hospital	Number of cases (total visits in brackets): Not admitted to hospital	Total
1	33 (33)	22 (22)	55 (55)
2	13 (26)	13 (26)	26 (52)
3	2 (6)	8 (24)	10 (30)
4	3 (12)	-	3 (12)
6	-	1 (6)	1 (6)
10	1 (10)	-	1 (10)
15	1 (15)	-	1 (15)
Total	53 (102)	44 (78)	97 (180)

Calculation of Costs to Cases and Visitors Associated with Hospital Treatment

	Number of journeys	Number of miles*	Rate per mile (pence)†	Total cost (£)
Journeys by cases:				
Assumption I				
All journeys	1,621	12,319.6	16.47	2,029.04
Assumption II				
Public transport	82	623.2	16.47	102.64
Car and taxi	1,298	9,864.8	27.07	2,670.40
				2,773.04
Journeys by visitors:				
Assumption I				
All journeys	6,848/2§	26,022.4	16.47	4,285.89
Assumption II				
Public transport	342	2,599.2	16.47	428.09
Car and taxi	5,480	41,648.0	27.07	11,274.11
				11,702.20

* number of miles = number of journeys x 7.6 (average distance from hospital)

† public transport rate .. .. .. = 16.47 pence per mile; public sector car mileage allowance = 27.07 pence per mile

§ to avoid excessive overestimation it was assumed that visitors travelled in groups of at least two, and so estimated numbers of journeys, and therefore costs, were halved.

Assumption I: all journeys were costly irrespective of method of travel and public transport rate was applied to all;

Assumption II: differential costs were applied according to method of transport; thus public transport rate was applied to appropriate journeys, public sector car allowance to travel by private car or taxi, and zero cost was applied to journeys by foot and "other" or unspecified.

Family Costs of Medical Treatment : GP Consultations

	Number of journeys	Number of miles*	Rate per mile (pence)†	Total cost (£)
Journeys by cases:				
Assumption I				
All journeys	6,385	11,493.0	16.47	1,892.90
Assumption II				
Public transport	528	950.4	16.47	156.63
Car and taxi	4,319	7,774.2	27.07	2,104.48
				2,261.01
Journeys by accompanying persons:				
Assumption I				
All journeys	1,069	1,924.2	2.00	38.48
Assumption II				
Public transport	85	153.0	16.47	25.20
Car and taxi	727	1,308.6	27.07	354.24
				379.44
	Number of items		Patient contribution per item‡	
Prescribed medicines	1,052		£2.60	2,735.20

* number of miles = number of journeys x 1.8 (average distance from surgery)

† public transport rate .. .. .. = 16.47 pence per mile; (rate for accompanying persons = 2.00 pence per mile)

‡ 1988/89 prescription costs

Assumption I: all journeys were costly irrespective of method of travel and public transport rate was applied to all;

Assumption II: differential costs were applied according to method of transport; thus public transport rate was applied to appropriate journeys, public sector car allowance to travel by private car or taxi, and zero cost was applied to journeys by foot and "other" or unspecified.

Length of Illness and Restriction on Activity

Type of case	Number of cases	Days of illness: Number	Days of illness: Average	Days of illness: Range
In hospital (227)				
confined to bed	171	817	4.8	1- 24
able to get up	150	636	4.2	1- 23
At home (1,151)				
confined to bed	665	3,484	5.2	1- 32
able to get up	763	8,421	11.0	1- 90
able to go out	418	4,407	10.5	1- 93
activities not restricted	286	3,167	11.1	1- 98
Total	1,151	20,932	18.2	1-254

Details of illness not specified: 250 days; 78 cases

Includes individuals also kept off work post recovery, or symptomless excreters, because of category of employment.

Total and Average Tangible Costs* by Health Care Demand Group

Categories of cost	In hospital n = 227 (£)		Visited by GP n = 422 (£)		Visited surgery n = 490 (£)		No consultations n = 90 (£)		Total n = 1,229 (£)	
	T	A	T	A	T	A	T	A	T	A
Public Sector Costs										
Investigation	24,073	106	44,753	106	51,965	106	9,545	106	130,336	106
Treatment costs:										
GP consultations	7,474	33	16,277	39	7,616	16	0	0	31,367	
hospital services	193,591	853	7,044	17	6,864	14	1,356	15	208,855	
ambulance	3,457	15	205	5	0	0	0	0	3,662	
prescription items	1,663	7	3,271	8	2,496	5	171	2	7,601	
Total	206,185	908	26,797	69	16,976	35	1,527	17	251,485	205
Families and Society										
Treatment-related costs	9,046	40	2,857	7	3,021	6	259	3	15,183	
Other losses/expenditure	34,329	151	34,122	81	36,790	74	5,867	65	111,108	
Total	43,375	191	36,979	88	39,811	80	6,126	68	126,291	103
Lost production	123,944	546	170,538	404	168,306	343	20,081	223	482,869	392
Total	397,577	1,751	279,067	667	277,058	564	37,279	414	990,981	806

* at 1988 prices

T = total; A = average

Table 4n.11

Total and Average Tangible Costs* by Severity Index Group

Categories of cost	Group 1 n = 19 (£)		Group 2 n = 105 (£)		Group 3 n = 290 (£)		Group 4 n = 509 (£)		Group 5 n = 192 (£)		Group 6 n = 114 (£)		Total n = 1,229 (£)	
	T	A	T	A	T	A	T	A	T	A	T	A	T	A
Public Sector Costs														
Investigation	2,015	106	11,135	106	30,755	106	53,979	106	20,362	106	12,090	106	130,336	106
Treatment costs:														
GP consultations	128	7	1,629	16	6,526	23	13,324	26	6,328	33	3,433	30	31,368	
hospital services	358	19	8,413	80	29,897	103	80,789	159	52,464	273	36,935	324	208,856	
ambulance	-	-	117	1	322	1	1,582	3	1,055	5	586	5	3,662	
prescription items	20	1	420	4	1,702	6	3,416	7	1,289	7	754	7	7,601	
Total	506	27	10,579	101	38,447	133	99,111	195	61,136	318	41,708	366	251,487	205
Families and Society														
Treatment-related costs	4	20	541	5	2,432	8	6,403	13	3,203	17	2,603	23	15,186	
Other losses/expenditure	178	9	2,910	28	20,848	72	44,930	88	30,080	157	12,170	107	111,116	
Total	182	29	3,451	33	23,280	80	51,333	101	33,283	174	14,773	130	126,302	103
Lost production	6,169	325	18,856	180	85,094	293	214,375	421	104,256	543	54,119	475	482,869	392
Total	8,872	487	44,021	420	177,576	612	418,798	823	219,037	1,141	122,690	1,077	990,994	806

* at 1988 prices

T = total; A = average

Numbers of Faecal Specimens Tested
for Persons Working in "At Risk" Occupations

Occupation	Number of persons	Number of specimens	Average
Medical:			
doctor	4	5	
nurse	31	156	
other health professional	4	-	
ancillary worker/porter	16	80	
Total	55	241	4.4
Welfare/teaching:			
nursery/playgroup	5	11	
school teacher	18	67	
welfare worker	6	18	
Total	29	96	3.3
Food production:			
waiter/steward/barman	12	63	
other catering worker	37	167	
food retailer	13	81	
Total	62	311	5.0
Grand total	146	648	4.4
Average specimens: all cases			3.2
Average specimens: all jobs			3.1

Data derived from cost survey

Appendix 5b

ASSUMPTIONS MADE IN COST-BENEFIT STUDY OF POULTRY IRRADIATION

1. Since poultry production in England and Wales is greater than for Scotland it was assumed that 10 plants, each processing 100,000 tonnes per annum would be operated on a regional basis; thus each would have a similar capacity to that suggested by Yule et al (1986). This would adequately cope with UK poultry meat production which was 1.014 million tonnes in 1988 (MLC, 1991).

The costs of the ten plants would be (1988 prices):

Capital costs:	buildings, equipment	£57,064,560
	land	£ 650.000
Recurrent costs:	overheads, employment	£ 7,120,940
	additional transport	£ 1,016,000
	product promotion	£ 1,000,000
Costs in year 1:		**£66,851,500**
Recurrent (depreciating) costs:		**£ 9,136,940**

This incorporated the further assumption that this approach takes full advantage of any economies of scale which would also offset at least some of the additional storage costs incurred. However, to counter the possibility that all costs were not offset a weighting was added to cover the construction and maintenance of cold storage facilities at the irradiation plant. These were equivalent to 25%, 50% and 75% of the irradiation plant capital and recurring costs. These estimates were also assumed to incorporate other unforseen costs resulting from transport and storage.

2. Since plants would be regionally based rather than at the producer site additional transport costs based on the marginal extra cost of diverting product to the irradiation plant on the way to centralised distribution depots were included. These were derived from poultry industry estimates of the marginal cost of transporting one tonne, carcass weight, an extra 50 miles (£1 per tonne) on normal delivery routes to distribution depots.

3. It was also assumed that an additional cost for promotion of the product would be incurred. This was based on Government expenditure of £1 million on a food safety leaflet campaign in 1988 (unpublished information) and taken to indicate Government willingness to pay to promote food safety. There is no information available on the effectiveness of food safety education in the UK, however, Krug and Rehm (1983) estimated the costs of this approach were low compared with an estimated moderate level of success in reducing foodborne illness.

4. Overall costs were based on the irradiation plant having a 15 year life and to calculate the net present value for that period (at 1988 prices) and to test the sensitivity of the assumptions a series of discount rates (3%, 5%, 7%, 10%) were applied to recurring costs (maintenance and promotional costs).

5. The cost of land was not discounted and treated as a capital cost. It could be argued that the site, because of the nature of the work carried out would decline in value and this would serve to increase the net benefits over the 15 year period.

6. It was assumed that there would be a linear relationship between the amount of poultry irradiated and a decline in human salmonellosis due to poultry. Thus the net benefit would be maximised when all poultry was irradiated (Yule et al, 1986). Therefore, it was assumed for this study that all poultry meat would be irradiated in order to demonstrate the maximum potential benefits from such an approach.

7. For the purpose of this study it was assumed that irradiation would result in virtual elimination of poultry borne salmonellosis. Since the actual level of poultry-borne infection is not known, although assumed to be high, the calculation of the costs of illness were based on assumptions that 10%, 25% and 50% of salmonella infections were from this source.

Appendix 5c

TABULATED FLOW OF COSTS AND BENEFITS FOR VARIOUS ASSUMPTIONS OF IRRADIATION COSTS AND COSTS OF SALMONELLOSIS

Assumption 1. Basic cost of irradiation at minimum cost of salmonellosis (1988 prices)

Year	Total cost of irradiation	Savings from reduction in salmonellosis low (10%)	mid (25%)	high (50%)	Net cash flow low	mid	high
1	66,851,500	23,100,000	57,750,000	115,500,000	-43,751,500	-9,101,500	48,648,500
2	9,136,940	23,100,000	57,750,000	115,500,000	13,963,060	48,613,060	106,363,060
3	9,136,940	23,100,000	57,750,000	115,500,000	13,963,060	48,613,060	106,363,060
4	9,136,940	23,100,000	57,750,000	115,500,000	13,963,060	48,613,060	106,363,060
5	9,136,940	23,100,000	57,750,000	115,500,000	13,963,060	48,613,060	106,363,060
6	9,136,940	23,100,000	57,750,000	115,500,000	13,963,060	48,613,060	106,363,060
7	9,136,940	23,100,000	57,750,000	115,500,000	13,963,060	48,613,060	106,363,060
8	9,136,940	23,100,000	57,750,000	115,500,000	13,963,060	48,613,060	106,363,060
9	9,136,940	23,100,000	57,750,000	115,500,000	13,963,060	48,613,060	106,363,060
10	9,136,940	23,100,000	57,750,000	115,500,000	13,963,060	48,613,060	106,363,060
11	9,136,940	23,100,000	57,750,000	115,500,000	13,963,060	48,613,060	106,363,060
12	9,136,940	23,100,000	57,750,000	115,500,000	13,963,060	48,613,060	106,363,060
13	9,136,940	23,100,000	57,750,000	115,500,000	13,963,060	48,613,060	106,363,060
14	9,136,940	23,100,000	57,750,000	115,500,000	13,963,060	48,613,060	106,363,060
15	9,136,940	23,100,000	57,750,000	115,500,000	13,963,060	48,613,060	106,363,060
Total	194,768,660	346,500,000	866,250,000	1,732,500,000	151,731,340	671,481,340	1,537,731,340

Assumption 2. Basic cost of irradiation + 25% at minimum cost of salmonellosis (1988 prices)

Year	Total cost of irradiation	Savings from reduction in salmonellosis			Net Cash Flow		
		low (10%)	mid (25%)	high (50%)	low	mid	high
1	83,060,375	23,100,000	57,750,000	115,500,000	-59,960,375	-25,310,375	32,439,625
2	10,917,175	23,100,000	57,750,000	115,500,000	12,182,825	46,832,825	104,582,825
3	10,917,175	23,100,000	57,750,000	115,500,000	12,182,825	46,832,825	104,582,825
4	10,917,175	23,100,000	57,750,000	115,500,000	12,182,825	46,832,825	104,582,825
5	10,917,175	23,100,000	57,750,000	115,500,000	12,182,825	46,832,825	104,582,825
6	10,917,175	23,100,000	57,750,000	115,500,000	12,182,825	46,832,825	104,582,825
7	10,917,175	23,100,000	57,750,000	115,500,000	12,182,825	46,832,825	104,582,825
8	10,917,175	23,100,000	57,750,000	115,500,000	12,182,825	46,832,825	104,582,825
9	10,917,175	23,100,000	57,750,000	115,500,000	12,182,825	46,832,825	104,582,825
10	10,917,175	23,100,000	57,750,000	115,500,000	12,182,825	46,832,825	104,582,825
11	10,917,175	23,100,000	57,750,000	115,500,000	12,182,825	46,832,825	104,582,825
12	10,917,175	23,100,000	57,750,000	115,500,000	12,182,825	46,832,825	104,582,825
13	10,917,175	23,100,000	57,750,000	115,500,000	12,182,825	46,832,825	104,582,825
14	10,917,175	23,100,000	57,750,000	115,500,000	12,182,825	46,832,825	104,582,825
15	10,917,175	23,100,000	57,750,000	115,500,000	12,182,825	46,832,825	104,582,825
Total	235,900,825	346,500,000	866,250,000	1,732,500,000	110,599,175	630,349,175	1,496,599,175

Assumption 3. Basic cost of irradiation + 50% at minimum cost of salmonellosis (1988 prices)

Year	Total cost of irradiation	Savings from reduction in salmonellosis			Net Cash Flow		
		low (10%)	mid (25%)	high (50%)	low	mid	high
1	99,269,250	23,100,000	57,750,000	115,500,000	-76,169,250	-41,519,250	16,230,750
2	12,697,410	23,100,000	57,750,000	115,500,000	10,402,590	45,052,590	102,802,590
3	12,697,410	23,100,000	57,750,000	115,500,000	10,402,590	45,052,590	102,802,590
4	12,697,410	23,100,000	57,750,000	115,500,000	10,402,590	45,052,590	102,802,590
5	12,697,410	23,100,000	57,750,000	115,500,000	10,402,590	45,052,590	102,802,590
6	12,697,410	23,100,000	57,750,000	115,500,000	10,402,590	45,052,590	102,802,590
7	12,697,410	23,100,000	57,750,000	115,500,000	10,402,590	45,052,590	102,802,590
8	12,697,410	23,100,000	57,750,000	115,500,000	10,402,590	45,052,590	102,802,590
9	12,697,410	23,100,000	57,750,000	115,500,000	10,402,590	45,052,590	102,802,590
10	12,697,410	23,100,000	57,750,000	115,500,000	10,402,590	45,052,590	102,802,590
11	12,697,410	23,100,000	57,750,000	115,500,000	10,402,590	45,052,590	102,802,590
12	12,697,410	23,100,000	57,750,000	115,500,000	10,402,590	45,052,590	102,802,590
13	12,697,410	23,100,000	57,750,000	115,500,000	10,402,590	45,052,590	102,802,590
14	12,697,410	23,100,000	57,750,000	115,500,000	10,402,590	45,052,590	102,802,590
15	12,697,410	23,100,000	57,750,000	115,500,000	10,402,590	45,052,590	102,802,590
Total	277,032,990	346,500,000	866,250,000	1,732,500,000	69,467,010	589,217,010	1,455,467,010

Assumption 4. Basic cost of irradiation + 75% at minimum cost of salmonellosis (1988 prices)

Year	Total cost of irradiation	Savings from reduction in salmonellosis low (10%)	mid (25%)	high (50%)	Net Cash Flow low	mid	high
1	115,478,125	23,100,000	57,750,000	115,500,000	-92,378,125	-57,728,125	21,875
2	14,477,645	23,100,000	57,750,000	115,500,000	8,622,355	43,272,355	101,022,355
3	14,477,645	23,100,000	57,750,000	115,500,000	8,622,355	43,272,355	101,022,355
4	14,477,645	23,100,000	57,750,000	115,500,000	8,622,355	43,272,355	101,022,355
5	14,477,645	23,100,000	57,750,000	115,500,000	8,622,355	43,272,355	101,022,355
6	14,477,645	23,100,000	57,750,000	115,500,000	8,622,355	43,272,355	101,022,355
7	14,477,645	23,100,000	57,750,000	115,500,000	8,622,355	43,272,355	101,022,355
8	14,477,645	23,100,000	57,750,000	115,500,000	8,622,355	43,272,355	101,022,355
9	14,477,645	23,100,000	57,750,000	115,500,000	8,622,355	43,272,355	101,022,355
10	14,477,645	23,100,000	57,750,000	115,500,000	8,622,355	43,272,355	101,022,355
11	14,477,645	23,100,000	57,750,000	115,500,000	8,622,355	43,272,355	101,022,355
12	14,477,645	23,100,000	57,750,000	115,500,000	8,622,355	43,272,355	101,022,355
13	14,477,645	23,100,000	57,750,000	115,500,000	8,622,355	43,272,355	101,022,355
14	14,477,645	23,100,000	57,750,000	115,500,000	8,622,355	43,272,355	101,022,355
15	14,477,645	23,100,000	57,750,000	115,500,000	8,622,355	43,272,355	101,022,355
Total	318,165,155	346,500,000	866,250,000	1,732,500,000	28,334,845	548,084,845	1,414,334,845

Assumption 5. Basic cost of irradiation at maximum cost of salmonellosis (1988 prices)

Year	Total cost of irradiation	Savings from reduction in salmonellosis			Net Cash Flow		
		low (10%)	mid (25%)	high (50%)	low	mid	high
1	66,851,500	33,100,000	82,750,000	165,500,000	-33,751,500	15,898,500	98,648,500
2	9,136,940	33,100,000	82,750,000	165,500,000	23,963,060	73,613,060	156,363,060
3	9,136,940	33,100,000	82,750,000	165,500,000	23,963,060	73,613,060	156,363,060
4	9,136,940	33,100,000	82,750,000	165,500,000	23,963,060	73,613,060	156,363,060
5	9,136,940	33,100,000	82,750,000	165,500,000	23,963,060	73,613,060	156,363,060
6	9,136,940	33,100,000	82,750,000	165,500,000	23,963,060	73,613,060	156,363,060
7	9,136,940	33,100,000	82,750,000	165,500,000	23,963,060	73,613,060	156,363,060
8	9,136,940	33,100,000	82,750,000	165,500,000	23,963,060	73,613,060	156,363,060
9	9,136,940	33,100,000	82,750,000	165,500,000	23,963,060	73,613,060	156,363,060
10	9,136,940	33,100,000	82,750,000	165,500,000	23,963,060	73,613,060	156,363,060
11	9,136,940	33,100,000	82,750,000	165,500,000	23,963,060	73,613,060	156,363,060
12	9,136,940	33,100,000	82,750,000	165,500,000	23,963,060	73,613,060	156,363,060
13	9,136,940	33,100,000	82,750,000	165,500,000	23,963,060	73,613,060	156,363,060
14	9,136,940	33,100,000	82,750,000	165,500,000	23,963,060	73,613,060	156,363,060
15	9,136,940	33,100,000	82,750,000	165,500,000	23,963,060	73,613,060	156,363,060
Total	194,768,660	496,500,000	1,241,250,000	2,482,500,000	301,731,340	1,046,481,340	2,287,731,340

Assumption 6. Basic cost of irradiation + 25% at maximum cost of salmonellosis (1988 prices)

Year	Total cost of irradiation	Savings from reduction in salmonellosis			Net Cash Flow		
		low (10%)	mid (25%)	high (50%)	low	mid	high
1	83,060,375	33,100,000	82,750,000	165,500,000	-49,960,375	-310,375	82,439,625
2	10,917,175	33,100,000	82,750,000	165,500,000	22,182,825	71,832,825	154,582,825
3	10,917,175	33,100,000	82,750,000	165,500,000	22,182,825	71,832,825	154,582,825
4	10,917,175	33,100,000	82,750,000	165,500,000	22,182,825	71,832,825	154,582,825
5	10,917,175	33,100,000	82,750,000	165,500,000	22,182,825	71,832,825	154,582,825
6	10,917,175	33,100,000	82,750,000	165,500,000	22,182,825	71,832,825	154,582,825
7	10,917,175	33,100,000	82,750,000	165,500,000	22,182,825	71,832,825	154,582,825
8	10,917,175	33,100,000	82,750,000	165,500,000	22,182,825	71,832,825	154,582,825
9	10,917,175	33,100,000	82,750,000	165,500,000	22,182,825	71,832,825	154,582,825
10	10,917,175	33,100,000	82,750,000	165,500,000	22,182,825	71,832,825	154,582,825
11	10,917,175	33,100,000	82,750,000	165,500,000	22,182,825	71,832,825	154,582,825
12	10,917,175	33,100,000	82,750,000	165,500,000	22,182,825	71,832,825	154,582,825
13	10,917,175	33,100,000	82,750,000	165,500,000	22,182,825	71,832,825	154,582,825
14	10,917,175	33,100,000	82,750,000	165,500,000	22,182,825	71,832,825	154,582,825
15	10,917,175	33,100,000	82,750,000	165,500,000	22,182,825	71,832,825	154,582,825
Total	235,900,825	496,500,000	1,241,250,000	2,482,500,000	260,599,175	1,005,349,175	2,246,599,175

Assumption 7. Basic cost of irradiation + 50% at maximum cost of salmonellosis (1988 prices)

Year	Total cost of irradiation	Savings from reduction in salmonellosis			Net Cash Flow		
		low (10%)	mid (25%)	high (50%)	low	mid	high
1	99,269,250	33,100,000	82,750,000	165,500,000	-66,169,250	-16,519,250	66,230,750
2	12,697,410	33,100,000	82,750,000	165,500,000	20,402,590	70,052,590	152,802,590
3	12,697,410	33,100,000	82,750,000	165,500,000	20,402,590	70,052,590	152,802,590
4	12,697,410	33,100,000	82,750,000	165,500,000	20,402,590	70,052,590	152,802,590
5	12,697,410	33,100,000	82,750,000	165,500,000	20,402,590	70,052,590	152,802,590
6	12,697,410	33,100,000	82,750,000	165,500,000	20,402,590	70,052,590	152,802,590
7	12,697,410	33,100,000	82,750,000	165,500,000	20,402,590	70,052,590	152,802,590
8	12,697,410	33,100,000	82,750,000	165,500,000	20,402,590	70,052,590	152,802,590
9	12,697,410	33,100,000	82,750,000	165,500,000	20,402,590	70,052,590	152,802,590
10	12,697,410	33,100,000	82,750,000	165,500,000	20,402,590	70,052,590	152,802,590
11	12,697,410	33,100,000	82,750,000	165,500,000	20,402,590	70,052,590	152,802,590
12	12,697,410	33,100,000	82,750,000	165,500,000	20,402,590	70,052,590	152,802,590
13	12,697,410	33,100,000	82,750,000	165,500,000	20,402,590	70,052,590	152,802,590
14	12,697,410	33,100,000	82,750,000	165,500,000	20,402,590	70,052,590	152,802,590
15	12,697,410	33,100,000	82,750,000	165,500,000	20,402,590	70,052,590	152,802,590
Total	277,032,990	496,500,000	1,241,250,000	2,482,500,000	219,467,010	964,217,010	2,205,467,010

Assumption 8. Basic cost of irradiation + 75% at maximum cost of salmonellosis (1988 prices)

Year	Total cost of irradiation	Savings from reduction in salmonellosis			Net Cash Flow		
		low (10%)	mid (25%)	high (50%)	low	mid	high
1	115,478,125	33,100,000	82,750,000	165,500,000	-82,378,125	-32,728,125	50,021,875
2	14,477,645	33,100,000	82,750,000	165,500,000	18,622,355	68,272,355	151,022,355
3	14,477,645	33,100,000	82,750,000	165,500,000	18,622,355	68,272,355	151,022,355
4	14,477,645	33,100,000	82,750,000	165,500,000	18,622,355	68,272,355	151,022,355
5	14,477,645	33,100,000	82,750,000	165,500,000	18,622,355	68,272,355	151,022,355
6	14,477,645	33,100,000	82,750,000	165,500,000	18,622,355	68,272,355	151,022,355
7	14,477,645	33,100,000	82,750,000	165,500,000	18,622,355	68,272,355	151,022,355
8	14,477,645	33,100,000	82,750,000	165,500,000	18,622,355	68,272,355	151,022,355
9	14,477,645	33,100,000	82,750,000	165,500,000	18,622,355	68,272,355	151,022,355
10	14,477,645	33,100,000	82,750,000	165,500,000	18,622,355	68,272,355	151,022,355
11	14,477,645	33,100,000	82,750,000	165,500,000	18,622,355	68,272,355	151,022,355
12	14,477,645	33,100,000	82,750,000	165,500,000	18,622,355	68,272,355	151,022,355
13	14,477,645	33,100,000	82,750,000	165,500,000	18,622,355	68,272,355	151,022,355
14	14,477,645	33,100,000	82,750,000	165,500,000	18,622,355	68,272,355	151,022,355
15	14,477,645	33,100,000	82,750,000	165,500,000	18,622,355	68,272,355	151,022,355
Total	318,165,155	496,500,000	1,241,250,000	2,482,500,000	178,334,845	923,084,845	2,164,334,845

Appendix 5d

ASSUMPTIONS MADE IN COST-BENEFIT STUDY OF COMPETETIVE EXCLUSION

Four options to the use of CE and antibiotic treatment were considered and these are described below*:

In calculating the costs of treatment the following were taken into account:

i. Each breeder hen will produce 114 live, day old chicks.

ii. 1988 UK production of poultry was 1.014 million tonnes at an average weight per bird of 3.5lbs, therefore 2.2308×10^9 lbs were produced.

iii. Costs of full treatment for a breeder (initial treatment with baytril and broilact with a third receiving a subsequent repeat treatment) was 11.4p per bird.

iv. Costs of full treatment for broiler chicks (furazolidone for 10 days and broilact) was 1.62p per bird.

Option 1. Breeder flocks only were treated with baytril plus CE:
Cost = 0.03p per lb x $(2.2308 \times 10^9)/100$ = £669,240.

Option 2. Broiler chicks only treated with furazolidone plus CE:
Cost = 0.46p per lb x $(2.2308 \times 10^9)/100$ = £10,261,680.

Option 3. Breeders and broilers treated as Options 1 and 2 above:
Cost = 0.49p per lb x $(2.2308 \times 10^9)/100$ = £10,930,920.

Option 4. Breeders treated as Option 1 and broilers with CE only:
Cost = 0.44p per lb x $(2.2308 \times 10^9)/100$ = £9,815,500.

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*The costs of baytril and furazolidone (antibiotics) and broilact (commercial CE preparation) and the costs of the alternative treatment options were supplied by members of the poultry industry.

1. In order to assess the potential benefits it was assumed that the options were applied nationally.

2. It was not assumed that the results of adopting CE would have uniform results in all breeder and broiler flocks but it was assumed that nationally reductions in human salmonellosis in the range 1% - 10% would be achieved.

3. It was assumed that adoption of CE would not displace or replace hygiene procedures currently employed by the poultry industry. Indeed the maintenance of hygiene standards would be essential in order to limit the contamination potential of infected birds which may enter the production cycle. Costs related to these activities would thus remain unchanged.

4. It was assumed that CE would be used in combination with antibiotic treatment of both breeder chicks (and adult birds in about one third of flocks) and broiler chicks (D Lanning and J Anderson, personal communication). Antibiotics, Baytril in breeder flocks and furazolidone in broilers, would be used initially to eliminate gut carriage of salmonellas before treatment with Broilact, a commercially produced CE culture.

5. The costs of treatment under the various options were compared with the minimum and maximum tangible costs of human infection.

6. For this analysis, only benefits in terms of decreased costs in human infection were considered. Calculation of poultry industry costs were based on current productivity levels in poultry flocks. However, there may also be benefits to poultry producers in terms of decreased mortality and morbidity in chickens resulting in greater productivity. In a more detailed study these would need to be offset against the actual costs of treatment.

Appendix 5e

AREAS OF CONSUMER CONCERN ABOUT FOOD IRRADIATION

Consumer resistance to irradiation falls into several areas and includes concerns about both the safety of the food and loss of nutritional status resulting from degradation of some components such as vitamins. Whilst some of these concerns are legitimate, considerable research shows others to have little or no basis in fact. For example, extensive studies have shown that at the doses approved for the irradiation of food, radioactivity is not induced in the product (Becker, 1983). Some changes in flavour may be detected but Urbain (1983) found that in beef these were not detectable below irradiation doses of 2.5 kGy. Thayer (1990), in a review of the benefits and concerns relating to food irradiation indicated that production of radiation resistant mutants was 'highly unlikely'; that free radicals produced in meat and poultry disappeared rapidly and in any case there was no evidence of foods containing high levels of free radicals having any adverse effects in feeding studies in rats; that peroxides or hydroperoxides which might be formed would be metabolised any differently from foods known to contain such substances.

In contrast, concern about loss of vitamins in irradiated foods has some basis. Fox et al (1989) demonstrated considerable loss of thiamine in irradiated cooked and raw pork and chicken although there was no significant loss of other B vitamins studied (riboflavin, niacin, pyridoxine and cobalamin). Proteins and carbohydrates were not significantly affected at normal food irradiation doses (Murray, 1983) and there appear to be negligible changes in the fatty acid profiles of irradiated chicken (Rady et al, 1988).

Other concerns about effects on altered spoilage flora populations may be real. Thayer (1990) reported survival of **Clostridium botulinum** spores on meat, and toxin production has been reported. However, this appeared to be associated with reduced use of nitrite or sodium chloride in such products. Where 2.5% sodium chloride was included in turkey meat **C. botulinum** toxin production was inhibited.

Thus extensive reviews of the safety of foods irradiated up to 10 kGy have failed to show any toxicological hazard and only limited effects on the nutritional status of products including poultry (Advisory Committee on Irradiated and Novel Foods, 1986; Thayer et al, 1987). In addition, long term feeding studies in rats, mice and dogs failed to show any adverse nutritional or toxicological effects (Nadkarni, 1980; Thayer et al, 1987).

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A REVIEW

The economic implications of human salmonella infection

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1. INTRODUCTION

The economic losses associated with salmonella infections have attracted increasing attention in developed countries in recent years, in particular in the United States, Canada and Europe including the UK, although the impact may well be greater in developing countries for which little data is available. Financial costs are not only associated with investigation, treatment and prevention of human illness but may affect the whole chain of food production. Thus, the costs of salmonellosis, as with other foodborne illness, fall into both the public and private sectors and may be surprising, both in terms of the levels of costs incurred and the variety of areas affected.

In the public sector, resources may be diverted from preventative activities into the treatment of patients and investigation of the source of infection. In the private sector considerable financial burdens may be imposed on industry in general and on the food industry in particular, and last but not least on the affected individual and his or her family.

This review examines the rationale behind the economic evaluation of salmonellosis which is probably the major recorded cause of foodborne infection in most developed countries. The description of national costing studies and costs relating to individual outbreaks indicate the potential value of such studies in the economic evaluation of procedures designed to prevent foodborne illness. Where estimated costs are quoted these are given in the currency reported in the original paper.

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2. FACTORS RESULTING IN INCREASED INTEREST IN ECONOMIC EVALUATION OF SALMONELLOSIS

Three factors in particular have influenced economists and others to direct their attention to the financial and social impact of salmonella infection. The first has been the dramatic increase in the number of cases of salmonella infection recorded in recent years. In England and Wales the number of isolations reported to the Public Health Laboratory Service Communicable Diseases Surveillance Centre (CDSC) rose from under 5000 in 1965 to over 25 000 in 1989 (Galbraith *et al.* 1987; Galbraith 1990). Since the mid 1980s this increase has been due almost entirely to one serotype, *Salmonella enteritidis*, suggesting that the increase is real and not an artefact of surveillance (Fig. 1).

The experience in England and Wales is not unique and increases in recorded salmonella infection have also been reported from North America and Europe (Archer & Kvenberg 1985; Manning 1988; Todd 1990; Gerigk 1990). In particular, increased *Salm. enteritidis* infection has been recorded in many countries (Rodrigue *et al.* 1990).

Second, there is a growing recognition that the costs associated with salmonella infection in particular, and foodborne illness in general, are high. Estimates have variously indicated annual costs of salmonellosis in the United States of billions of dollars and at hundreds of millions of dollars in Canada (Archer & Kvenberg 1985; Todd 1989a, b). Although these costs are dependent on estimates of the numbers of unreported cases and appear to assume the same range of severity of illness in both unreported and reported cases, they nonetheless indicate the significant

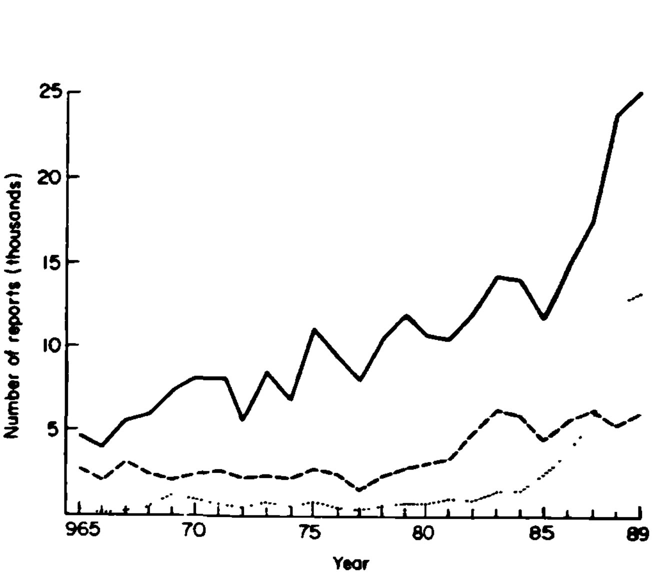

Fig. 1 Laboratory reports of salmonella infection, England and Wales 1965–89. ——, all salmonellas; ····, *Salmonella enteritidis*; ---, *Salm. typhimurium*

economic impact of these infections. The costs of salmonella infection in the UK are estimated to run into millions of pounds annually for reported cases alone (Sockett & Roberts 1989).

Costs of individual outbreaks can be very high and may range from thousands to millions of pounds (or dollars) depending on the type of outbreak implicated. Thus the range of, mainly direct, costs associated with 10 salmonella outbreaks in food service establishments in the USA and Canada between 1962 and 1984 was $57 423 to $699 400 whilst the costs resulting from an outbreak at a European Summit Conference in Holland in 1981 was at least US $317 000 (Todd 1985a; Beckers *et al.* 1985). Where an individual food product is involved the associated costs may be even higher. An analysis of five salmonella outbreaks due to manufactured foods which occurred in North America between 1973 and 1982 gave direct costs which ranged from $36 400 to $62 million (Todd 1985b). Similarly high costs were associated with two outbreaks in the UK in 1982 and 1985 which were due to manufactured foods and gave total direct costs of £379 thousand and £14·6 million (Roberts *et al.* 1989; Anon. 1986).

A third, more general, factor has been the growth in interest in the sphere of economic evaluation in the health care and public health sectors. For example, government policy in the UK has focused attention on the need to contain public expenditure. This has taken place against a background of increasing public expectation with relation to health care and the development of increasingly sophisticated and expensive diagnostic and treatment procedures. The resulting pressures on resources have led to a greater emphasis on the need to evaluate both the efficacy and efficiency of public sector activities (Roberts 1989). Thus the need for economic appraisal of disease costs and the benefits of preventive measures is now well established.

3. CATEGORIES OF COSTS

In the UK the costs associated with salmonellosis fall under the headings of public sector costs and costs to society (Fig. 2). These may be subdivided into tangible costs which are easily measured in monetary terms, e.g. medical costs and lost production and intangible costs such as loss of leisure and pain and discomfort, which are not. These in turn are often further divided into direct costs which fall on the affected person or implicated food producer and indirect costs which fall on other family members, e.g. travel costs to visit the sick relative. There are some ambiguities about the use of these terms in the literature which give rise to difficulties in comparing results. To minimize confusion in this review, results are presented as only tangible or intangible costs.

Public sector costs relate mainly to the investigation of cases or outbreaks and to the treatment of the ill person. As such these activities will impose costs, for example in the UK, on local authority Environmental Health Departments, public health physicians, laboratories and government departments such as the Department of Health and the Ministry of Agriculture, Fisheries and Food as well as medical services including general practices and hospitals. These costs therefore ultimately fall on the public purse.

Costs to society act at three distinct levels. Firstly, there are costs of illness which fall directly on the person who is ill and their immediate family (Sockett & Roberts 1991). Secondly, there are costs to the national economy which relate to sickness absence from work; these can be considerable and have been shown to be a major component of costs related to illness (Krug & Rehm 1983; Curtin 1984; Sockett & Roberts 1991). Thirdly, the association of a particular food product or retail outlet with an outbreak of food poisoning can have major repercussions for the producer, manufacturer or retailer.

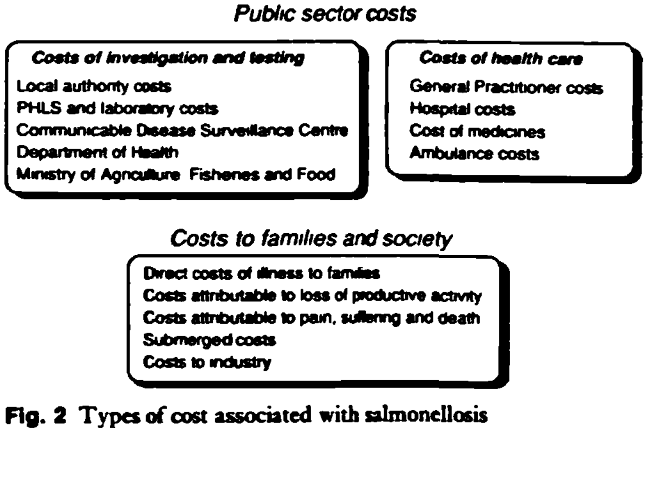

Fig. 2 Types of cost associated with salmonellosis

3.1 Tangible costs

The tangible public sector and society related costs associated with seven salmonella outbreaks reported in the UK since 1981 are summarized in Table 1 (Cohen *et al.* 1983; Neilson 1984; Anon. 1986; Yule *et al.* 1988; Barnass *et al.* 1989; Roberts *et al.* 1989; Sockett, unpublished). The largest society related costs were recorded in two outbreaks which were due to manufactured foods having wide distribution nationally. In both of these outbreaks major costs to the manufacturer resulted from the recall and destruction of the product and, in the outbreak of *Salm. ealing* infection, included capital expenditure on plant cleaning, renovation and equipment replacement. A similar result was reported by Todd (1985b) who identified recall related costs in five outbreaks due to manufactured foods in North America which varied from $124·4 thousand to $58·3 million; accounting for 24–99% of the total costs of the outbreaks. Further, indirect, costs to the manufacturer involved in the *Salm. ealing* outbreak resulted from a £22 million loss in the sale value of the company, a decline in public confidence in the product and the eventual closure of a production unit with the loss of about 200 jobs (Anon. 1986; Erlichman 1989). Litigation costs resulting from claims made against food manufactures and retailers have been significant in outbreaks reported in the US and Canada (Todd 1989a). Although this has not been a reported feature of outbreaks recorded in the UK (Sockett & Roberts 1989) the settlement of claims paid by a major airline in the UK following a salmonella outbreak in 1984, which resulted in over 600 cases in passengers and two associated deaths, was very expensive (Burslem *et al.* 1990), and may have been in the region of several million pounds (British Airways Press Office).

These types of costs, however, are largely distributional and contained within the food industry. The overall effect on the economy is therefore likely to be minimal unless long term unemployment results from, for example, loss of public confidence in a product leading to a cut back in production or plant closure.

In certain circumstances, however, the government may step in to support a sector of the food industry if public confidence in a product is seriously undermined, and in this situation the taxpayer will ultimately pay the bill. In 1988, for example, the British government made £7 million available to support the egg industry, following the reported association of the increase in *Salm. enteritidis* PT4 infection with contaminated poultry and eggs (Anon. 1988, 1989).

The remaining society costs were related mainly to costs of lost production due to sickness absence and to costs falling to ill individuals and their families. Where lost production was considered it was a major component of the economic impact of illness. For example in an outbreak due to contaminated unpasteurized milk in 1981, Cohen *et al.* (1983) estimated lost productive output cost nearly £40 000, almost half of all the tangible costs of the outbreak. In a recent study in England and Wales, adults in full or part time employment were off work for six and a half days on average and lost production was over half of all costs identified (Sockett & Roberts 1991).

The impact of infection on the affected individual and his or her family is twofold. Firstly, there are a wide variety of financial costs resulting from additional unforseen expenditure and losses resulting from cancelled arrangements. Secondly, there are difficult to value, intangible effects resulting from the general discomfort of illness and the disruption caused to normal activities, absence from schooling and loss of leisure time. The tangible family costs have been explored in detail in a recent study of the national costs of salmonellosis in England and Wales (Sockett & Roberts 1991). Large components of the costs identified in the study were associated with seeking medical

Table 1 Tangible costs associated with seven salmonella outbreaks reported in the United Kingdom since 1981

Year	Serotype (number of cases)	Food	Public Sector Cost (£)	Society Cost (£)	Total (£)
1981	*Salm. typhimurium* (654)	Raw milk	43 493	39 737	83 230
1982†	*Salm. napoli* (245)	Chocolate	104 312	274 646	378 958
1982	*Salm. typhimurium* (31)	Not known	3 234	3 280	6 514
1985*†	*Salm. ealing* (76)	Milk powder	163 012	14 500 000	14 663 017
1985	*Salm. thompson/ infantis* (242)	Turkey	34 612	79 240	113 852
1987	*Salm. heidelberg* (19)	Poultry	23 146	2 197	25 343
1987	*Salm. typhimurium* (19)	Raw milk	11 392	>6 500	>17 892

* Direct costs only.
† Outbreaks due to manufactured foods.
Source: Anon. 1986; Barnass *et al.* 1989; Cohen *et al.* 1983; Neilson 1984; Roberts *et al.* 1989; Sockett unpublished data; Yule *et al.* 1988.

attention and expenditure on cleaning and disinfection agents, and with lost opportunities resulting from cancelled arrangements and disrupted holidays. Although these items accounted for only 10% of the overall tangible costs identified they nonetheless represented a considerable impact on the budgets of individual families.

3.2 Intangible costs

In addition to the tangible costs of illness considered so far there are important intangible costs which are not directly measurable in financial terms. They are, however, important to the overall description of the impact of illness, and, although there is disagreement about the methods of valuing intangible costs, the need to take such costs into account is agreed by economists. The intangible costs of illness include loss of leisure time, pain and suffering and in a small proportion of cases of salmonella infection, death. Death represents both a human loss to the families involved with possible financial implications as well; it may also represent a cost to the economy in terms of the loss of the future production potential of the individual.

The approaches to valuing loss of life are based either on values derived from decisions made elsewhere in the public sector, measuring the lost future production potential of an individual or attempt to measure the value an individual places on his or her life, or a combination of these (Misham 1982; Landefeld & Seskin 1982; Cohen *et al.* 1983). The values identified are likely to be high and can result in a considerable increase in the estimated overall costs of illness. The values ascribed to lives lost may therefore have an important influence on the evaluation of preventive measures using, for example, the cost benefit approach (Cohen *et al.* 1983; Yule *et al.* 1988; Roberts *et al.* 1989). Thus, in a study of *Salm. napoli* infection in 1982 estimated values for loss of life ranged between £190 000 and £15 million depending on the method used (Roberts *et al.* 1989). Positive cost-benefit ratios for secondary prevention in this study were calculated for public sector and society related costs and a 23·3 fold rate of return was calculated on the overall cost of the outbreak, which incorporated the lowest value of life estimate. Using a higher value of life estimate would have markedly increased the rate of return.

4. NATIONAL COSTS OF SALMONELLA INFECTION

Very few studies of the national costs of foodborne illness in general or salmonellosis in particular have been reported in the literature. Broad estimates for the costs of infectious intestinal disease were calculated at $23 billion a year in the United States (Garthright *et al.* 1988). Costs of foodborne bacterial disease were estimated at $4·8 billion for 1987 in the US by Roberts (1988); salmonellosis accounted for $1·4 billion of the total and was the largest single cause although staphylococcal food poisoning and campylobacter infection also accounted for about $1 billion each. Both of these studies sought to estimate costs associated with medical care and lost productivity including, in the study by Roberts (1988), productivity losses due to deaths which was a major component of the costs. Other costs were excluded and the amounts stated therefore represented the minimum costs of disease. Comparable estimates of the annual costs of salmonellosis were also reported by Archer & Kvenberg (1985) (£1·9–£2·3 billion) and Todd (1989b) ($4 billion) for the United States and Todd (1989a) ($846 million) for Canada, although the range of cost categories included in these studies was wider.

The costs derived in these studies were dependent on estimates of the numbers of cases of illness occurring each year and on cost per case data obtained from a small number of outbreaks. In most of these studies little allowance was made for the range of severity of illness which may vary from very mild to death, and the average cost per case may not have adequately reflected the relatively mild illness which is probably experienced by most infected persons. Exceptions were the study by Roberts *et al.* (1989) in which allowance was made for mild illness in most persons in estimating cost attributed to unreported cases and the study by Roberts (1988) in which cases were ascribed to one of four severity classes: deaths, hospitalized cases, cases who consulted a doctor but were not admitted to hospital and mild cases who did not consult a doctor.

4.1 West Germany and Canada

Two detailed studies of national costs of salmonella infection in 1977 were reported from the then Federal Republic of Germany (FRG) and Canada (Table 2) (Krug & Rehm 1983; Curtin 1984). The studies relied, to some extent, on assumptions about levels of under-reporting of salmonellosis and there were differences in the categories of costs included, particularly in relation to intangible costs, e.g. pain and discomfort and death. Important tangible costs relating to the investigation of cause of illness (German study) and financial implications of illness to families were excluded. However both studies indicated that loss of production to the economy due to sickness absence (including loss of housewives' time in the Canadian study) and intangible losses associated with the value of leisure time foregone were major items. Both studies included estimates of losses incurred as a result of infection in cattle, pigs and poultry in Germany (DM114·2 million) and poultry in Canada (Canada $2·8 million). Despite the methodological difficulties the WHO recognized the importance of such studies

Table 2 Estimated annual costs of human salmonella infection in Germany (1977) and Canada (1977)

Category of costs	FRG (DM 1000s)	CANADA (Can $1000s)
Medical and investigation	19 555 (18)	5 467 (7)
Lost production	24 282 (23)	28 734 (34)
Loss of consumption	17 260 (16)	
Loss of leisure	45 902 (42)	47 464 (57)
Loss of life		1 986 (2)
Other costs	1 151 (1)	
Total	108 150 (100)	83 651 (100)

Percentages in brackets.
Source: Krug & Rehm 1983; Curtin 1984.

and has stated that 'similar studies should be conducted in other European countries' (Anon. 1982).

4.2 England and Wales

Until recently, estimates of the costs of salmonella infection in England and Wales were based on extrapolations from studies of outbreaks adjusted for estimates of numbers of unreported cases and assumptions about severity of illness (Sockett & Roberts 1989). However, a detailed survey of almost 1500 persons with confirmed salmonella infection was carried out in 1988 and 1989. The aim of the study was to examine, in detail, costs to the public sector involved in the investigation and treatment of cases, to quantify costs to the economy from illness related absence from work and to identify costs to the affected individual and his or her family. Preliminary tangible costs per case related to the sample were £789. Therefore tangible costs associated with about 23 000 reported identifications recorded in 1988 were £18·1 million (Table 3) (Sockett & Roberts 1991). Half (51%) of this was due to lost production resulting from sickness absence or time off work to care for relatives. A third of identified costs were associated with the investigation and treatment of cases and the remainder reflected costs incurred by the ill person and their family.

No intangible costs have been included at this stage, but inclusion of the lowest estimates for loss of life would have almost doubled the total. In addition, a small proportion of cases may develop chronic illness including reactive arthritis and malabsorption syndromes which may require treatment over short or extended periods of time (Jayson & Grennon 1983; Archer 1984, 1985). Thus the preliminary results of this study represented the minimum annual costs of reported salmonellosis.

Table 3 Estimated costs of laboratory confirmed and reported salmonella infection in England and Wales: 1988

Category of costs	£ (1000s)
Public Sector costs:	6 849
Costs to families and economy:	
(a) costs to families	1 796
(b) lost production	9 499
	11 295
Total	18 144

5. COSTS AND BENEFITS OF PREVENTING SALMONELLA INFECTION

The value of economic appraisal of salmonellosis is threefold. Evaluating the total costs of diseases in general is helpful, firstly in bringing to public attention an essentially preventable illness; and, secondly, in identifying those areas, particularly in the public sector, which consume resources. However, the third and probably most valuable contribution, concerns the evaluation of procedures designed to limit or prevent the spread of infection.

The national costing studies for FRG and Canada sought to evaluate, through the cost-benefit analysis approach, which particular measure or combination of measures could be expected to achieve significant reductions in human salmonella infection. Because of the lack of data relating to some specific cost categories and reliance on expert opinion in some areas, the main value of these studies was to provide a model for looking at costs and benefits rather than provide firm estimates of these. Nevertheless, estimations of the costs and expected success of a number of control measures indicated that, for example, hygiene education aimed at both the domestic user and the food service sector would have benefit in reducing infection. However, elimination of contamination earlier in the food chain would seem more controllable and reliable, and therefore a more desirable objective.

Few detailed cost-benefit studies of control measures for limiting salmonellosis are reported in the literature. The potential economic advantages of primary prevention aimed at reducing initial product contamination was illustrated by Cohen *et al.* (1983) and Yule *et al.* (1988). Cohen concluded that financial benefits would result from a ban in the sale of unpasteurized milk in Scotland if this reduced milk associated salmonellosis. Sharp (1988) has shown that milkborne salmonella and campylobacter infection is now almost non-existent in Scotland following introduction of such a ban in 1983.

The benefits of secondary prevention which act to limit an outbreak once it has happened were examined in a study of a salmonella outbreak due to contaminated chocolate in 1982 (Roberts *et al.* 1989). In this instance the outbreak was stopped when only 20% of the product had been sold. The investigation costs of the outbreak at the point it was stopped were then compared with projected costs of the outbreak to both the public sector and families and society, had it continued until stocks of the imported product were exhausted. This showed that for every £1 expended on investigation there was a saving of £3·50 to the public sector and of £1·50 in lost production.

6. CONCLUSIONS

The relatively few published studies of the financial implications of salmonellosis suggest the costs are high. Most authors indicate the figures they present are underestimates or based on incomplete data. Taking into account the large number of, probably mild, unreported cases and the small numbers of cases who develop chronic sequelae the true economic impact of salmonellosis is likely to be of some significance. Economic analysis has an important contribution to make to the prevention and control of these infections, particularly when applied to the assessment of the relative costs and benefits of alternative preventative strategies.

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Use of DNA probes in the study of silage colonization by *Lactobacillus* and *Pediococcus* strains

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P S. COCCONCELLI, E. TRIBAN, M. BASSO AND V. BOTTAZZI 1991 A technique to monitor lactic acid bacteria inoculants in silage, based on specific DNA probes, was developed and used to evaluate the colonization properties of two strains of *Lactobacillus plantarum* and one strain of *Pediococcus pentosaceus* which were used as maize silage inoculants in farm conditions. The results indicated that these three strains were able to dominate the natural microflora of the silage, representing more than the 95% of the bacterial biomass of the maize silage. These studies indicate that the colony hybridization with specific DNA probes may be an effective method for monitoring bacteria and evaluating the colonization properties of inoculants in maize silage.

INTRODUCTION

The success of ensilage process in conserving forage hinges on the rapid lowering of pH that hampers the breakdown of plant proteins, the reduction of nutritive quality of the forage and the growth of undesirable bacteria (Weinberg *et al.* 1988). Central to the process of pH reduction is the transformation of water-soluble carbohydrates in organic acids, mainly lactic acid, mediated by lactic acid bacteria (Pitt *et al.* 1985). The use of cultures of homofermentative lactic acid bacteria as silage additives reduces the time spent at high pH, results in a rapid decrease of pH and increases the preservation of forage (Pitt & Leibensperger 1987). Particularly important in modelling the inoculants is the choice of strains with high colonization ability that result in a domination over the natural microflora of the silage (Dellaglio 1985).

The study of the behaviour of specific bacteria added as inoculants in natural environments has been limited by the lack of suitable systems for monitoring specific strains. In addition, the prospect of using genetically modified lactic acid bacteria (Chassy 1987; Scheirlink *et al.* 1989) in open environments has highlighted the need of additional techniques for the detection of a specific bacterial strain. The technique of DNA transfer from colonies to filters and the hybridization of single-stranded labelled DNA, allows the identification of a specific DNA sequence and these techniques have been successfully used to detect and identify specific bacteria among the other colonies isolated from the environment (Attwood *et al.* 1988; Diels & Mergeay 1990; Walia *et al.* 1990).

The objective of this work was the development of a system for the detection and monitoring of lactic acid bacteria in maize silage and the use of this technique for the study of colonization properties and for the evaluation of the effectiveness of three strains of lactic acid bacteria added as inoculants. We have therefore developed a system of colony hybridization for *Lactobacillus* and *Pediococcus* and we have designed DNA probes specific enough to detect the inoculants in the midst of environmental microflora of maize silage.

In this paper we report the use of specific DNA probes for the monitoring of two strains of *Lactobacillus plantarum* and one of *Pediococcus pentosaceus* during the process of maize ensilage in farm conditions and we demonstrate the ability of these strains to colonize the silage and to dominate over the natural microflora.

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MATERIALS AND METHODS

Bacterial strains and media

The strains L38 and L40 of *Lact. plantarum* and the strain P60 of *Ped pentosaceus* were used as inoculants. These strains were isolated from maize silage and selected from among 500 freshly isolated homofermentative lactic acid bacteria for their properties of oxygen tolerance, lactic acid

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The social and economic impact of salmonellosis

A report of a national survey in England and Wales of laboratory-confirmed salmonella infections

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SUMMARY

This study presents the findings of a national survey of 1482 cases of salmonellosis reported to Environmental Health Departments in England and Wales between August 1988 and March 1989. A questionnaire survey of ill individuals and the environmental health officers who investigated them sought information about costs which were imposed upon public health authorities, the health sector, individuals and their families and the costs to the wider economy in terms of lost production.

Costs of £996339 were identified. Over half (£507555) resulted from lost production due to sickness absence and more than a third (£392822) were costs to the public sector which resulted from health care and local authority investigation of cases. The remaining costs (£95962), although the smallest proportion of the total, indicated that salmonellosis can have a significant impact on affected individuals and their families.

INTRODUCTION

The social and economic impact of food-borne disease is considerable. It imposes costs upon the public sector, on industry, in particular the wholesale and retail food industry, and very importantly upon the infected person and their family. The illness may result in admission to hospital and, in a small proportion of cases, in death.

Public sector costs fall on the health sector which is directly involved in the care of patients and on public health and hospital laboratory and environmental health services responsible for investigating the illness. Costs to industry include the loss of productivity of those who are ill and those who may need to be off work to care for them and those who are prevented from working as a precautionary measure to stop the spread of infection. It also involves the loss of business, productivity and goodwill of industries or organizations implicated in an outbreak. Most importantly, it imposes costs upon the persons who are ill and those who care for them. These costs include those directly attributable to the illness, those associated with the lost opportunities to carry out normal daily activities and the pain, suffering and sometimes death which results from the illness.

As food-borne infection is preventable, these costs are potentially avoidable. It would, therefore, appear desirable to measure the costs of the illness in order to establish some measure of the savings that might accrue from preventive activity.

Despite the long history of the use of economic evaluation in the field of public health, for example, Calkin's use of Farr's work to calculate the impact of sanitary legislation in England at the end of the nineteenth century [1], there has been little interest, until recently, in using the economic calculus to examine the economic implications of food borne illness or the benefits of its prevention.

Now, however, three factors have combined to direct attention towards the use of economic evaluation in this area. Firstly, the number of cases of salmonellosis recorded in England and Wales has risen from 4000–7000 a year in the mid 60's to over 23000 in 1988 [2, 3]. Similar trends have been experienced in other developed countries. Manning, for example, reported an increase in salmonella infections recorded in the United States from 11 per 100000 in 1971 to more than 27 per 100000 in 1985 [4]. Although these increases may be partly due to increased ascertainment, the recent increase in England and Wales has resulted from a sharp rise in reporting of only one type of salmonella. Since doctors cannot selectively test for this salmonella the trend is probably real. Secondly, evidence is accumulating which suggests that the costs associated with salmonella infection and other food-borne illnesses are high [5, 6]. Thirdly, the increased attention that has been placed on containing public expenditure and pressures on resources in these sectors has led to greater emphasis on the assessment of the efficacy and efficiency of public sector activities [7].

Many studies of the costs of food borne disease, mainly salmonellosis, have examined the financial consequences of individual outbreaks. In such cases the number of persons affected is likely to be known fairly accurately and the resources employed in treatment and investigation of cases relatively easy to identify. The purpose of many of these types of study has been to identify and enumerate the categories of costs. However, some recent studies have attempted to relate costs to preventive activities. Such studies have assessed the benefits of primary prevention such as monitoring by health officers, pasteurization of milk and irradiation of poultry; and secondary prevention such as intervention to curtail outbreaks [8–11]. Some studies have attempted to extrapolate the costs of individual outbreaks to give estimates of the national impact of disease. This, however, is not a very reliable method of ascertaining national costs as the cost profiles of individual outbreaks can vary substantially and bold assumptions may have to be made about the quality of data, levels of under reporting and the severity of the illness.

Studies to ascertain the national costs of salmonellosis have been undertaken in Canada and Germany; both studies relied upon assumptions about the sources of infection and the levels of infection in humans and animals based on surveys of expert opinion [12, 13]. Although this approach may not necessarily lead to very accurate estimates they were compatible with the aims of the studies which were to provide a framework for looking at costs of illness and benefits of prevention. The main difference between the studies was the inclusion of costs relating to loss of life and the restriction of animal costs to those falling on the poultry industry in the Canadian study. The studies produced estimates of DM 108 million for costs of human infection and a further DM 132 million for costs of animal infections in the Federal Republic of Germany and $84 million in Canada. These costs are considerable though still a small proportion of the respective health budgets of these countries.

There is very little detailed information available on the national costs of salmonellosis in England and Wales. Work derived from an earlier study of an outbreak led to further explorations to test the methodology for estimating the costs of infection [8]. A survey of 66 cases of salmonella infection which occurred in Birmingham in 1985 indicated that a questionnaire survey could provide detailed information on the costs of illness to the individual and the public sector [14]. Estimations of the full impact of the infection on industry would require a different methodology.

In response to the current increase in reporting, a survey to examine, in detail, the financial and social costs of salmonella infection was conducted in England and Wales between 1 August 1988 and 31 March 1989 which included periods of peak and low reporting.

METHODS

Estimates of the costs of salmonellosis were obtained by a questionnaire survey carried out in collaboration with Environmental Health Departments (EHDs). Letters inviting collaboration were sent to all Chief Officers of EHDs in England and Wales. Two hundred and nineteen agreed to collaborate in the study by participating in the survey and by distributing questionnaires. A case was defined as any person with laboratory-confirmed salmonella infection. Environmental Health Officers were requested to pass questionnaires together with a letter explaining the purpose of the study and a prepaid addressed return envelope to all cases which came to their notice during the study period, irrespective of the age of the person or the severity of their illness. This would normally be via either the notification of cases of food poisoning by medical practitioners to the Proper Officer for the District, or in the course of investigating notified cases or outbreaks. This approach was taken to minimize, as far as possible, any tendency to select particular groups of individuals.

The survey was in the form of a two part questionnaire linked by a common study number. Part A was designed to identify costs associated with the investigation of cases. It was addressed to the investigating Environmental Health Officer (EHO) who was asked to give details of the number of specimens submitted for laboratory testing from cases, contacts and foods or environment. Details of travel costs, administration and 'other' costs, and details of the time spent on the investigation by the various grades of staff were requested.

At the completion of the investigation by the EHO Part B was given to cases for completion. Part B was used to assess the use of health care services, including general practitioner and hospital services, and the impact on the economy due to sickness-related absence from work. The tangible and intangible costs of illness to the case and his or her family were also explored in detail in the questionnaire.

The questionnaires were designed to be self coded except for occupation, family relationships and incidental expenditure which were centrally coded.

Based on the previous year, 1987, it was estimated that a sample equivalent to 5–10% of reports expected during the study period would include the salmonella serotypes which normally account for 95% of reports to the Communicable Disease Surveillance Centre (CDSC). The number of questionnaires distributed to each Environmental Health Department was related to the proportion of the total population in England and Wales covered by that local authority district. Each department was asked to continue to distribute questionnaires until their quota was exhausted or the study ceased, whichever occurred first.

Non-responders were identified by receipt of a part A form from an EHO without a corresponding part B in the following 2 months. Such non-responders were sent a reminder letter together with a replacement part B questionnaire and a further short questionnaire asking for reasons for non-compliance.

Parts A and B of the questionnaire were checked for accuracy and consistency. The data were entered onto computer and verified by on-screen review; finally the data sets were analysed for duplicate entries and coding inconsistencies.

RESULTS

The number of questionnaires distributed was taken to be the total of all Part A only, Part B only, and Parts A+B together returned. On this basis 1601 questionnaires were distributed. One hundred and nineteen were excluded because the onset of illness fell outside the study period, infection was due to another organism or the questionnaire was unreadable. The results presented are therefore based on the remaining 1482 questionnaires. Of these, 1229 included Part B questionnaires returned by infected individuals indicating a response rate from cases of 83%. The date of onset of illness was available for 1266 (85%) cases; most, 87%, were ill between July and December 1988 and the remaining 13% in the first 3 months of 1989.

The specific salmonella serotype identified was recorded for 745 cases. Most were *Salmonella enteritidis* (61%), *S. typhimurium* (21%) or *S. virchow* (4%) and all other serotypes recorded accounted for the remaining 15% of cases (Table 1). This distribution matched closely the distribution of salmonella serotypes reported to the CDSC during the same period (PHLS Communicable Disease Surveillance Centre, unpublished). The major proportion of cases (875 cases, 59%) were sporadic, that is they had no known association with other cases. A further 423 (29%) were part of a single household (family outbreaks) or were associated with outbreaks following meals at restaurants, receptions etc (general outbreaks). No information was given for the remaining 184 (12%). Twenty per cent (303) cases became ill or were infected whilst on holiday outside the British Isles. Most had visited either European countries (59%), in particular Spain, or North Africa (29%). This distribution probably reflected the popularity of Mediterranean

Table 1. *Comparison of distribution of serotypes in study sample with reports to CDSC during study period from laboratories in England and Wales*

Serotype	Number and proportion (%) of identifications	
	Study sample	Reports to CDSC
S. enteritidis	451 (60·5)	11999 (58·9)
S. typhimurium	156 (20·9)	4373 (21·4)
S. virchow	30 (4·0)	812 (4·0)
Other serotypes	108 (14·5)	3219 (15·8)
Total	745	20403

Table 2. *Occupational groups of 1223 cases*

Occupation	Male	Female	Not stated	Total
Pre school child	104	93	1	198
Schoolchild	65	74		139
Student	9	10		19
Full-time employed	311	202		513
Part time employed	6	146		152
Housewife		95		95
Retired	45	39		84
Unemployed	11	12		23
Total	551	671	1	1223

resorts with British holidaymakers and the possibility that persons with a recent history of travel abroad are more likely to be asked to submit a specimen for laboratory examination.

There were more females (55%) than males (45%) in the sample due entirely to an excess of adult females aged 15 and over. In general the age distribution of the sample was similar to the age distribution of all salmonella cases reported to CDSC in 1989 (the first year for which this information was available); although cases aged under 1 year and 65 years or over were under represented. However, the study sample showed significant differences when compared with the age distribution of the population of England and Wales, showing a marked excess of children aged under 5 years whereas the elderly (aged ⩾ 65 years) were considerably under represented. The reasons for this are unclear, but may indicate a greater likelihood that doctors will submit a specimen for laboratory tests when the patient is a young child. The severity of illness recorded ranged from symptomless excretion and mild diarrhoea to severe illness and death.

Details of occupation were given for 1223 cases (Table 2). The sample included 665 adults in full or part time employment. A further 23 persons of employable age were classified as unemployed. Of the 95 women described as housewives 15 were aged over 60 years (actual age not stated for 2 cases). School children and students accounted for 158 cases, and 198 cases were pre school children.

Public health costs of investigation and testing

The costs of investigation were £157162 (Table 3) and were based on answers provided by EHOs to part A of the questionnaire. Costs included investigation of the source of infection and payments for exclusion from work, if necessary, of those who were ill. Staff costs were calculated using information about the grade of staff employed, time spent on the investigation and their position on the salary scale, adjusted to take into account all costs of employment. Costs of laboratory testing were taken from PHLS estimates made in 1982 expressed as 1988/89 prices. These included staff time to conduct tests and costs of consumables [15].

No attempt was made to apportion capital costs of these institutions which are involved in multiple and varied activities. To apportion costs of the public health infrastructure would have involved a different and very extensive inquiry.

Costs to the health sector

Hospital costs

Two hundred and twenty seven (18·5%) respondents were admitted to hospital for an average of 6·4 days. The costs of a day in hospital were derived from Hospital Costing Returns for 1988 updated using the price index provided by the Department of Health (DoH) (Economic Advisors Office, DoH, personal communication). Costs per day of an acute medical admission in 1988/89 were estimated as £119. This rate was used to estimate the cost per case and the total cost to the health sector for the patients in the sample (Table 3).

Many patients were treated at Accident and Emergency departments (AED) or attended hospital Out-Patient departments (OPD) as a consequence of their illness. The costs of a first and subsequent attendance at each department was estimated, using the Hospital Costing Returns adjusted for 1988/89 prices. These amounted to £4289 and £16444 for AED and OPDs respectively.

Transport to and from hospital was sometimes made by ambulance and costs of ambulance journeys were estimated with the help of the York Ambulance Service. Differentiation was made between the cost of an emergency ambulance admission and discharge home by 'bus' ambulance (York Ambulance Service, personal communication) [16].

Some patients were accompanied to hospital by carers, some of whom stayed in hospital with child patients. It has not, as yet, been possible to estimate the cost to the hospital sector of those who stayed. It is possible that any costs were compensated for by saving nursing time, surveillance or attending to patients; but this is not clear.

General practice and community services

The major impact of salmonellosis on the general practice i.e. the ambulatory care sector of the health service was estimated. A total of 866 patients visited their doctors on average 2·2 times and 587 patients were visited at home by their doctor on average 2·1 times. Because of the way in which general practitioners (GPs) are paid for their services in the UK (capitation fee for registered patients, practice allowance and fee for service), it might be argued that there is no opportunity cost associated with consultation with GPs. However, it could also be argued that GPs are fully employed, busy people and that the time taken up by an additional patient who has salmonellosis precludes the doctors from doing something else almost as valuable, i.e. the opportunity cost is not zero. We have adopted the latter view and in consultation with the DoH and British Medical Association

Table 3. *Public sector costs*

	Total (£)
Public health costs	
Local authority (EHD)	85632 69
Laboratory testing	71529 40
	157162.09
Medical (NHS treatment costs	
General practice	31367.35
Hospital services	193642.25
Ambulance service	2959.50
Prescriptions (net cost to NHS)	7690 51
	235659.61
Total	**392821.70**

(BMA) have derived figures which approximate to the cost of a consultation £7) or visit by GP (£14.45) at 1988/89 prices. These gave an estimated total cost for the sample of £31367 (Table 3).

The patients may need the service of other staff from social or community services, but as the illness is sudden and acute, it is unlikely that these services are used, except in areas where visits by nurses instead of doctors are common. Cohen (Aberdeen) found high use in a rural area in Scotland but Sockett in a study in Birmingham found no use [10, 14]. We have no details of the use of these services for our sample.

Costs of medicines

The cost of treating cases of salmonellosis depends not only on what is the most effective treatment but also on the expectations of doctors and patients about the care required. On average 1·33 prescriptions per case were provided; the costs of these prescriptions were estimated using DoH cost data for 1988 89 (£6.33 per case) adjusted to take into account the proportion paid by patients for these prescriptions. The net cost to the NHS was £7691 and the cost per case was £6.26.

The total costs to the public sector of salmonellosis in our sample were £392822 a cost per case of £298. Sixty per cent of these costs fell upon the health sector for the treatment of cases and the remaining 40% were for public health activities by local authorities.

Costs to families and the economy

The costs to patients and famil'es

The guiding principle used to assess the costs to patients was to estimate how much it would cost to place them in the position in which they would have been had the infection not occurred. It was not assumed that these costs represented the value patients would place on avoiding the illness. The costs of the illness do however represent some minimum value of benefits. It could be argued that details of costs and a profile of the physical impact of the illness should be provided as background information in studies which attempt to ascertain benefits using the 'willingness to pay' approach Some of the costs fall directly upon those infected and other costs fall on family members and friends.

Table 4. *Family costs of illness*

	Total £
Costs of GP consultations	
Travel cases	1892.90
Travel accompanying persons)	38.48
Prescribed medicine patient contributions	2735.20
	4666.58
Costs of hospitalization	
Travel cases	2029.04
Travel visitors	4285.89
Trousseau	2630.75
Expenditure in OPD	78.29
	9023.97
Other family costs	
Additional expenditure	18020.65
Unexpected losses due to illness	9204.05
Expenditure losses from illness acquired abroad	55046.78
	82271.48
Total	**95962.03**

Costs of obtaining general practitioner services

The direct costs of receiving treatment from general practitioners is shown in Table 4. Forty one per cent of these costs were associated with travel by patients and others and 59% to those patients who were not exempt from prescription charges. The proportion exempt from charges in the sample was much less than that for the population as a whole who contribute to slightly less than 20% of items prescribed. This may be explained by the age structure and composition of our population which was largely composed of people under 65 years of age who were otherwise healthy.

Costs of hospitalization

Transport of patients and their visitors accounted for over two thirds of the costs of hospitalization (Table 4). A further third, however, was spent on incidental expenses associated with hospital stay. Some of these expenses, which people incur in order to present themselves appropriately in encounters with the health sector, have been described by Abel Smith as the Trousseau effect (B. Abel Smith, personal communication). These costs, whilst small, can be a burden on the budgets of families.

Other costs of the illness

Table 4 shows the costs which were specified by patients as having been incurred as a result of the illness; these included expenditure needed to cope with the illness. Over one third of these expenses related to medicines and medical care, and hygiene and communications accounted for a further 22% of the costs. These costs were largely predictable consequences of the illness. Individuals, however, faced a wide range of unpredictable costs which resulted from illness. Unforeseen expenditure and losses from cancelled arrangements included a large proportion of costs arising from spoilt holidays. It was assumed that people value a day's

Table 5. *Lost production*

		Days off work	Cost (£)
Fu t me :	Men	3552	174971 52
	Women	3199	108030.23
Part t me :	Men	39	1921 14
	Women	2547	86012 19
		9337	**370935.08**
Carers .	Men (P FT)	542	26698 92
	Women	936	31608 72
	Not known	15	656 25
		1493	**58963.89**
Total*		**10830**	**429898.97**
incl ding labour costs			**507554.98**

* Gender specific male rate: 49·26; female rate 33·77 ; Non-gender specific (rate: 43·75), total £559400.82 including labour costs.

holiday at least as much as the price they have paid for it. Some unforeseen expenses, including a lost honeymoon, represent some challenges for the economic calculus which we have not attempted to assess.

Lost productivity

By far the largest component (51 %) of the costs of salmonellosis was represented by lost production (Table 5). There is some debate about the extent to which absence from work affects productivity and in some instances the work will be made up either bv 'slack' in the system or by imposing extra work on other members of staff. Conversely, absence of a key individual may cause losses disproportionate to that person's apparent contribution. It was impossible to ascertain in our study the precise effects on productivity and the method chosen seems to be the least biased approximation to productivity loss. Some analysts take the position that there is no productivity loss if there is any unemployment in the system on the assumption that replacement staff can be taken on from the pool of unemployed. One could argue, however, that unemployment is a matter for the macro management of the economy and evaluation of health provision should not be unduly affected by the ebbs and flows of cyclical unemployment. In the case of salmonella infection presence or absence of unemployment is largely irrelevant as the periods of absence, in most cases, will be short and the costs of seeking alternative employees would be prohibitive.

The questionnaire requested information about the time off work by patients and those who cared for them as a result of their illness. This lost production was calculated as far as possible using estimated average earnings for men and women for the period of the study. These were adjusted for labour costs to assess the estimated value of the production lost. This figure was also adjusted to remove the differential payments made to men and women which raised the estimated losses to half a mill on pounds. We have not estimated 'time costs' which are not associated with l ss of work. We recognize that these costs are important and merit a more deta led analysis.

Table 6. *Summary of costs*

	Total cost £	Cost per case £
Public sector costs		
Local authority investigations*	85632.69	57.78
Laboratory costs*	71529.40	48.27
	157162.09	06.05
General practice costs	31367.35	25.52
Hospital services inc ambulance	196601.75	159.97
Prescribed medicines	7690.51	6.26
	235659.61	191.75
	392821.70	**297.80**
Families and economy		
Costs of treatment. GP	4666.58	3.80
Hospital	9023.97	7.34
Other costs of illness	82271.48	66.94
	95962.03	78.08
Loss production (gender specific)	507554.98	412.98
	603517.01	**491.06**
Total	**996338.71**	**788.86**

* 1482 cases. All other costs based on 1229 cases

Summary of costs

The costs derived from the questionnaire are summarized in Table 6. The costs were converted into costs per case by dividing local authority and laboratory costs by the relevant sample size, 1482. The costs per case for the remaining categories was based on the total of 1229 respondents. The cost per case was estimated as £789 and the total costs associated with the sample of patients studied was £996339.

The range in costs per case was however very wide and was particularly sensitive to the costs of hospitalization and to lost production. Thus, for cases admitted to hospital, treatment costs ranged from £119 for a patient admitted for 1 day to over £4000 for a patient in hospital for 34 days. This had a knock on effect resulting in corresponding increases in travel costs to families and friends visiting the patient. Similarly for patients off paid employment, the costs of lost production ranged widely depending on the number of days off.

DISCUSSION

The costs estimated in this study suggest that human salmonellosis is expensive to the public sector, industry and families. Based on the 23000 reported cases alone in 1988 public sector costs would have been about £6·8 million whilst costs to industry from lost production would have been £9·5 million. These are under estimates of the true costs since they take no account of costs of unreported cases, or estimates of costs of general discomfort of the illness or lives lost or indeed the longer term sequelae of infection [17].

This study was concerned solely with laboratory-confirmed cases and, in terms of the distribution of serotypes reported and the age distribution of cases, the sample accurately represented laboratory reported cases of salmonellosis recorded by CDSC. It could be argued that the cases ascertained in this study, because the had come to the notice of EHDs, would represent more severely ill persons. Although this was probably true, to some extent, the severity of illness in the sample ranged widely. Many more cases do not come to the attention of the authorities but still impose considerable disruption and discomfort on those affected and cause loss of productivity and increased use of general practitioner services. Adding such costs would substantially increase the costs of salmonellosis to the economy but as they would include many less severe cases they would reduce the average cost per case.

The costs identified in this study represented only a part of the impact of salmonellosis on patients and their families. Salmonellosis is an unpleasant condition and whilst no attempt was made to value pain and suffering in this study we attempted to compile a profile of the condition and its impact on the patient using a series of questions about the number of symptoms experienced their severity and the number of days spent in each state. It is intended that this work will be used subsequently as a basis for a health status measure for acute episodes of illness.

Three people included in our sample died whilst infected with salmonellae including two people who were in poor health. This is slightly less than we might predict for the sample size [15]. Questionnaires were returned by the families of two of these cases. Valuing life is a difficult and contentious area. In previous work using an approach also adopted by Cohen and colleagues [10] we provided estimates based on implicit value of life derived from decisions in the public sector, values based on the human capital approach and values based on the willingness to pay estimations. Even using the lower estimates, including the value of lives lost substantially increases the average cost per case of salmonellosis from £789 to £1200–1500. Willingness to pay values would raise the cost per case to approximately £6000.

This study has not estimated the costs of salmonellosis on firms which might be involved in an outbreak. Documented cases reported in other studies indicate the enormous sums which may be involved in such outbreaks which, in some instances, have resulted in withdrawal of products and closure of factories [5, 6, 9, 18–20]. Costs of treatment and containment to the agricultural industry as indicated by studies in Germany and Canada are also high [12, 13]. The estimates we give therefore need to be seen in the context of a potentially expensive but essentially preventable illness which so far as national reporting in the UK is concerned, has increased considerably in recent years. Reports suggest that similar trends are being recorded in many European countries and North America [21, 22].

It is therefore important to document as fully as possible the costs of illness. This will provide a basis for the economic analysis of preventive strategies. This may take the form of an analysis of the costs and benefits derived from preventive activities per se and may contribute to the decisions about choice of preventive strategies by the food industry at different points in food production.

Salmonellosis is only one of many food borne infections some of which are generally less severe but recorded in high numbers [3]. Others are reported in low numbers but may be very severe with a comparatively high associated mortality. It is hoped that this study will prov de a model for the study of these and other acute illnesses, and it is being d pted currently for major studies of gastrointestinal infections.

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Food poisoning outbreaks associated with manufactured foods in England and Wales: 1980-1989

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Summary

In the ten-year period, 1980-89, 294 reported outbreaks of food poisoning were associated with eating pre-cooked sliced meats, meat products and other manufactured foods in England and Wales, including 65 outbreaks in which the product was imported. Salmonellas were the most commonly reported agent, causing 132 (45%) of the outbreaks; other bacteria caused a further 51 (17%) outbreaks. The remainder were due to viruses (five outbreaks), scombrotoxin (60 outbreaks), or were of unknown cause (46 outbreaks).

The number of outbreaks associated with manufactured foods accounted for only a small proportion (less than 5%) of food poisoning outbreaks reported to CDSC during this period and needs to be set against the huge amounts of manufactured foods consumed. However, because of the quantities made and the widespread distribution of particular products, such outbreaks may affect many individuals who are geographically widespread.

Introduction

Outbreaks of foodborne disease associated with manufactured foods can have a considerable effect, both in terms of the numbers of people who become ill and the implications for the manufacturer: the product may be recalled and the manufacturer may bear considerable financial loss. This was highlighted in the United Kingdom by the ability of a contaminated tin of Argentinian corned beef to cause, through cross-contamination to other sliced meats, over 400 cases of typhoid in Aberdeen in 1964 and to damage for a time the credibility of the tinned corned beef industry[1].

Most manufactured products are distributed widely and a particular product may be marketed in more than one country. This trend is likely to increase with the formation of the single European market in 1992 and freer movement of products between member states. The quantities produced are often large and, if such a product is inadequately processed or becomes contaminated, many people may become ill and cases may be geographically widespread. In an outbreak in 1985, due to pasteurised milk from one dairy in the United States, over 16,000 culture confirmed cases of salmonellosis were recorded in northern Illinois and surrounding states, including over 2777 admitted to hospital, although the actual number ill was estimated to be over 150,000[2]. This paper reviews the available information on outbreaks associated with pre-cooked sliced meats, meat products and other manufactured foods reported to CDSC over the ten-year period, 1980-89, and considers some of the factors contributing to them as well as their economic implications.

Sources of data and definition of terms

Information about outbreaks was derived from summary reports to CDSC by laboratories and local authorities in England and Wales. For a small number of outbreaks, mainly those of national importance or outbreaks affecting large numbers of people in the community, supplementary information was available from more detailed investigation reports.

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An outbreak was defined as two or more cases of illness related by eating a common food item purchased and consumed in this country. Outbreaks where a single manufactured food or basic ingredient was the suspected vehicle of infection were included. Outbreaks in which it was unclear if the food was a manufactured item, and outbreaks listing multiple manufactured or non-manufactured food items, were excluded. As far as possible, outbreaks resulting directly from mishandling of foods during final preparation in the home or catering establishment were also excluded.

A manufactured food was defined as any product of the agricultural industry that had been converted into a consumer product by any process of heat treatment, drying or curing, or fermentation, etc. Thus, frozen or raw meat was excluded but foods pre-cooked before retail sale were included. Foods prepared "fresh" by the catering sector were excluded.

Results

A total of 294 outbreaks reported to be associated with UK produced or imported manufactured foods was recorded in the ten-year period, 1980-89, in England and Wales; an average of 29 each year (Table 1). These accounted for less than 5% of the 6240 outbreaks of food poisoning reported to CDSC during this period. The majority, 154 outbreaks, were ascribed to products manufactured in the UK; these included outbreaks where the suspect food was manufactured in the UK from basic ingredients, irrespective of the origin of those ingredients. In 75 outbreaks the source of the manufactured food was unclear although it was likely that, in the majority of these, the implicated food was produced in the UK. In 65 outbreaks the food associated with illness had been imported into the UK; that is, the finished product was sold without further processing to the consumer or the catering sector.

The agent causing illness was identified in 248 (85%) of the outbreaks recorded in table 1 and in 79 (26%) outbreaks it was also identified in the implicated food vehicle. Illness was due to salmonella infection in 132 (45%) outbreaks, and a further 51 (17%) were due to other food poisoning or foodborne bacteria. Five outbreaks were caused by virus infection, three due to small round structured viruses (SRSV) and two due to hepatitis A virus. Illness was due to scombrotoxin poisoning in 60 outbreaks and in the remaining 46 the aetiology of the illness was unknown.

Place of outbreak

Details about the place where the implicated food was eaten were available for 231 outbreaks (Table 2). Members of a single household were affected in just over one-third (82 outbreaks); the remainder (149 outbreaks) were general outbreaks affecting wider groups of people. The most important category of general outbreaks was that affecting the community in general (86); in the majority of these, cases were confined to the local community. However, at least 13 outbreaks in the period under review were of national importance, either because of the seriousness of the illness, the large number of people affected, or because the implicated product was distributed widely (Table 3). In eight of these outbreaks the product was manufactured in the UK and in five the product was imported. In most of these outbreaks the product was withdrawn from sale and public warnings were made advising that the product should not be eaten.

Types of food

Cooked foods (processed meats, meat pies, potted meats and paté)

Fifty-one percent (149) of the outbreaks reported were in this category (Table 1). Most (107) of these were due to salmonella infection. This category included 62 community-wide outbreaks due to contaminated meat products, including 43 where the product was made locally by small manufacturers, butchers or other shops. The majority of outbreaks in this category occurred in the summer months, suggesting that poor temperature control was a contributing factor.

The largest outbreak, due to salmonella infection, occurred in North Wales and North West England in July and August 1989 and was associated with eating cooked meats; mainly pork and ham. At least 545 persons were infected and the same strain, *Salmonella typhimurium* DT 12, which was isolated from many of the human cases, was also recovered from joints of cooked meat and work surfaces at a retail outlet[3].

In 81 outbreaks the most commonly reported vehicle of infection was a locally produced meat product. Six outbreaks

Table 1 Sources and vehicles of outbreaks (numbers of imported foods shown in parenthesis)

	Salmonella	Other bacteria	Viruses	Scombrotoxin*	Unknown	Total
Cooked foods (processed meats, meat pies, potted meats and paté)	107 (4)	24	–	–	18 (2)	149 (6)
Processed fish and shellfish	2	2 (1)	4	20	7 (1)	35 (2)
Tinned foods:						
meats	5	6 (2)	–	–	4 (2)	15 (4)
fish and shellfish	1	1	–	40 (40)	10 (7)	52 (47)
vegetables	–	–	–	–	1 (1)	1 (1)
cheese		–	–	–	1 (1)	1 (1)
Dairy products	6 (2)	12	–	–	1	19 (2)
Bakery products	7	3	1	–	1	12
Powdered foods	2	1	–	–	–	3
Other	2 (1)	2 (1)	–	–	3	7 (2)
Total	132 (7)	51 (4)	5	60 (40)	46 (14)	294 (65)

* Information from Bartholomew et al[4] and Gilbert R J and Scoging A C (personal communication)

Table 2 Location of outbreaks*

Category	Number	
Home (family outbreaks)	82	
General outbreaks	149	
Community†		86
Commercial catering¶		30
Institutional catering‡		20
Place of work**		10
Other, not stated		3
Total	231	

* Excludes scombrotoxin outbreaks
† resulting from foods purchased from local and/or multiple retail outlets
¶ Hotels, restaurants, receptions, clubs, public houses
‡ Hospital, old persons' home, school, college
** Canteen, other work place

Table 3 Outbreaks of national importance

Causal agent	Year	Food item and country of origin	Number ill
*Salmonella napoli**	1982	Chocolate, Italy	272
Unknown*	1982	Tinned salmon, N America	24
Salmonella gold-coast	1984	Paté, France	200
*Staphylococcus aureus**	1984	Pasta, Italy	47
Salmonella ealing	1985	Infant dried milk UK	>76
SRSV†	1985	Cockles, UK	>519
SRSV†	1986	Cockles, UK	>225
SRSV†	1987	Cockles, UK	>652
*Salmonella typhimurium**	1988	Salami sticks, W Germany	86
Unknown	1988	Cheese, UK	155
Clostridium botulinum	1989	Hazelnut yoghurt, UK	27
Salmonella manchester	1989	Autolysed yeast, UK	40
Salmonella typhimurium	1989	Cooked meat, UK	>545

* Products manufactured abroad
† Small round structured virus

were associated with imported foods. These included four outbreaks in which paté, produced in Belgium (2) or France (2), was implicated; one due to chopped ham from Denmark, and one due to salami sticks imported from Germany[4]. In the latter incident, 101 cases of *S. typhimurium* DT 124 infection were recorded in England and Wales, and the association between illness and eating the product was confirmed microbiologically and epidemiologically. Experimental studies described in the paper detailing the outbreak[4] indicated that the preparation process used did not have a major effect on the survival of salmonellas during fermentation, drying and storage in deliberately contaminated meat. However, the numbers of *S. typhimurium* DT 124 bacteria declined much faster at storage temperatures of 15-25°C compared with storage temperatures of 5-10°C.

Processed fish and shellfish

Thirty-five outbreaks associated with processed fish and shellfish were reported, including two where the product was imported.

Scombrotoxin poisoning was the most common cause and gave rise to 20 outbreaks affecting 59 persons; each outbreak affected two or three people. All of these outbreaks were associated with eating mackerel products, including smoked mackerel (18), mackerel paté (1) and filleted mackerel (1)[5] (RJ Gilbert and AC Scoging, PHLS Food Hygiene Laboratory; personal communication). The symptoms were compatible with a histamine-like reaction and may have resulted from ingestion of histamine produced in the flesh of spoiled fish[6].

Bivalve molluscan shellfish, in the form of cockles, were associated with eight outbreaks, including three characterised by gastroenteritis due to SRSV in which over 1300 people were affected (Table 3). The remaining outbreaks were associated with crustacean species (3) and processed fish (4).

Tinned foods

Sixty-nine outbreaks were associated with tinned foods. Tinned meat was implicated in 15, including four in which the product was imported (Argentina, Brazil, Denmark and Romania).

Tinned fish and shellfish were the most common products reported. The 52 outbreaks included 40 of scombrotoxin poisoning associated with: tuna, 24 (Far East and Pacific 14, Africa 4, S America 1 unknown 5); pilchards, 10 (S America 9, unknown 1); and sardines, 6 (Morocco 3, Portugal 2, unknown 1). Other tinned seafoods associated with illness were salmon (5), including an outbreak comprising a number of incidents in 1982, sardines (1), tuna (1), crab (2), oysters (2) and eel paté (1). The product was imported in seven of these incidents.

One outbreak was reported due to tinned haloumi cheese obtained in Cyprus and a single outbreak was associated with tinned tomatoes from Italy. One further outbreak, of botulism, in which tinned hazelnut conserve added to yoghurt acted as the vehicle of infection, is described in the next section.

Dairy products

The 19 outbreaks associated with dairy products (excluding the incident due to tinned haloumi cheese mentioned above) included two salmonella, five campylobacter and two yersinia outbreaks associated with milk that had reportedly been heat treated. It is likely in these outbreaks that either the heat process itself was inadequate or the milk was contaminated after pasteurisation[7-10]. Seven of the remaining outbreaks in this category were associated with eating cheese. This included 155 cases in 1988-89 associated with Stilton cheese made with unpasteurised milk. Although the aetiology of the illness was not determined, symptoms suggested a staphylococcal illness[11]. One outbreak was associated with pasteurised cream contaminated with *Bacillus cereus*.

Two outbreaks were associated with reconstituted powdered milk, including a major outbreak due to contaminated infant milk formula. Most of the 76 cases were infants and the association between illness and consumption of a particular dried milk product was confirmed epidemiologically and by isolation of *S. ealing* from cases, unopened packets of dried milk and environmental samples from the production plant[10]. Inspection of the inner lining of the spray-dryer identified a hole: insulation material and powder recovered from the area around the hole were contaminated with *S ealing*[12].

The largest outbreak of foodborne botulism recorded in the UK was reported in June 1989. Twenty-seven persons became ill after eating yoghurt flavoured with contaminated canned hazelnut conserve[13]. The investigators reported that the implicated conserve had been sweetened with aspartame rather than sugar and enquiries into the method of preparation of the conserve indicated that heat used in the manufacturing process was inadequate to destroy *Clostridium botulinum* spores[13].

Imported dairy products were implicated in two of the 19 outbreaks. One, in the early 1980s, was associated with semi-soft cheese from Turkey and a second, in 1989, was due to soft cheese from Ireland contaminated with *S. dublin*. This cheese was made from unpasteurised milk.

Bakery products

Of the 12 outbreaks associated with bakery products, seven were associated with cakes containing reconstituted fillings. Two were associated with bread contaminated with *Bacillus* species, and in a third outbreak bread was the only common food in a community-wide outbreak of hepatitis A infection[14]. One salmonella outbreak was associated with eating doughnuts, and in another salmonella outbreak lemon meringue pie produced by a local baker was associated with illness in 14 persons.

Powdered foods

Powdered foods, other than milk powder, were implicated in three outbreaks. The most important of these was attributed to nationally distributed savoury corn snacks containing autolysed yeast based powdered flavouring. A particular strain of an unusual salmonella serotype, *S. manchester*, was isolated from cases, mostly children, and from the yeast powder. *S. manchester* was also found in the roller drying area and other sites in the factory where the powder was manufactured[15].

Other foods

The remaining seven outbreaks did not fit any specific food category and included salmonella outbreaks due to contaminated artificial cream and orange juice, and three outbreaks of unknown aetiology associated with enteral feed, 'sherbet stix' and locally brewed beer. The other two outbreaks resulted in widespread illness in the community. In the first, in 1982, contaminated chocolate bars imported from Italy caused 245 recorded cases of *S. napoli* infection, mostly in young children[16]. Low levels of contaminating organisms were found in the bars but the mechanism of contamination was not demonstrated. In the second outbreak, in 1984, the vehicle of a *Staphylococcus aureus* food poisoning outbreak was imported pasta[17]. Incidents associated with the product, which was made in a factory in Italy, were also recorded in Italy and Luxembourg. An enterotoxin A producing strain of *S. aureus* was present in 94% of packets of egg lasagne examined and toxin and high organism counts (up to 2×10^8/g) were demonstrated in the product.

Discussion

The implication of a particular product as a cause of illness can have severe effects on the manufacturer, particularly where this results in public warnings and recall of the product. Thus, the economic effects on the manufacturer will not only include the direct costs of product recall and destruction, and capital expenditure to clean, renovate or replace equipment and work areas, but may also include indirect costs from legal action, loss of consumer confidence leading to a decline in sales, promotional costs and, in extreme cases, may result in plant closure[18]. In a comparison of seven salmonella outbreaks which occurred in the UK between 1981 and 1987, costs associated with the two due to manufactured products were considerably higher than the rest[19]. This was similar to the results of a study by Todd[20] who compared the costs of 17 outbreaks, mainly in North America, and estimated that the costs reflected the large quantities of product manufactured and their widespread distribution.

The risk factors associated with the outbreaks reviewed in this paper fell, largely, into three categories. Firstly, some sources of foods may be less safe than others, ie, certain raw materials are more likely to be contaminated, and the associated risks of infection from these materials may be enhanced in certain circumstances. For example, molluscan shellfish are often harvested from inshore waters or estuaries which may be subject to bacterial and viral contamination resulting from the discharge of sewage effluent; this can be further compounded by the ability of filter feeding bivalve molluscs to concentrate these micro-organisms[21,22]. Human illness may then occur when processing fails to destroy or remove contaminating bacteria and viruses[23]. Secondly, the process or treatment itself may be inadequate, or may be made inadequate as a result of changes in the procedure or formulations used in the process, or as a result of undetected damage to equipment[12]. Thus, removal of preservatives may not only reduce the shelf life of a product but may also have implications for the way it is stored. In the botulism outbreak, there was a change in the sweetening agent used in the implicated tins, and heating during the process did not destroy *C. botulinum* spores[13]. Fortunately, botulism is rare in this country and only 10 incidents have been recorded since 1922[24]. At least two others were associated with manufactured products; potted wild duck paste in 1922 and Alaskan tinned salmon in 1978[25,26]. Thirdly, the product may be subject to unsafe handling practices. The high proportion of outbreaks due to contaminated meat products – with most occurring in the summer months – and the demonstration of cross-contamination in some outbreaks indicate how poor handling and storage practices may result in illness.

The relatively small number of outbreaks reported to be associated with manufactured foods needs to be seen in the context of the huge amounts of food which are produced and consumed daily. For example, estimated meat consumption alone in the same ten-year period was estmated at 39.8 million tonnes in the UK, of which at least a quarter was processed meats[27]. However, there are major risks when things go wrong, and the importance of safe standards, careful assessment of production processes through such techniques as hazard analysis critical control point (HACCP)[28], responsible attitudes, and continued reinforcement of food hygiene principles for staff and management[29], should be emphasised. In addition, innovation in the way processes are monitored and risks and standards are assessed should be encouraged.

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Authors are invited to submit papers on all aspects of surveillance, prevention and control of communicable diseases to be considered for publication in the *Communicable Disease Report*. Manuscripts (two copies) should be double-spaced and not more than 4000 words in length including references (maximum 30) and sacrifice space for figures and tables. Short reports (400-1000 words highlighting important messages culled from outbreak investigations may be submitted for inclusion in the Outbreak Forum (see CDR Review issue of 16 August for further details). Manuscripts and their references should conform to the Vancouver style as set out in the "Uniform requirements for manuscripts submitted to biomedical journals" (BMJ 1991; 302: 338-41).

Listeriosis surveillance: 1990

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Summary

The annual numbers of reports of listeriosis in England, Wales and Northern Ireland received by the PHLS Communicable Disease Surveillance Centre (CDSC) and the Division of Microbiological Reagents (DMR) have shown remarkable changes in recent years. There was a near doubling in 1987 compared to 1986; a further increase in 1988; a sharp decline in 1989 (which occurred in the second half of that year) and, finally, the total in 1990 was the lowest since 1984. The rise and fall particularly (but not exclusively) involved pregnancy-associated cases and illness caused by serotype 4. The epidemiological and clinical features reported in 1990 were otherwise similar to those reported in previous years and in other countries. Patients with the non pregnancy-associated (also called 'adult/juvenile') type were in the majority, most of whom had an underlying disorder associated with impaired immunity.

The reason for the changes in reported incidence is not completely understood but is probably due to the emergence and disappearance of a common food source of the organism. There is, however, no cause for complacency. Diagnostic vigilance must be maintained and vulnerable groups should adhere to existing dietary advice.

Introduction

Listeriosis is a disease caused by the gram positive bacillus *Listeria monocytogenes*. It may present as septicaemia or meningoencephalitis, especially in the immunocompromised or elderly. Listeriosis acquired in pregnancy can infect the fetus, resulting in abortion, stillbirth, neonatal sepsis or meningitis. By contrast, maternal infection is rarely severe and often asymptomatic.

Most cases of listeriosis are sporadic, but common source outbreaks have been recognised (both in the UK and overseas) in which many foodstuffs have been implicated as vehicles of infection[1-5]. Sporadic listeriosis has also been associated, both epidemiologically and microbiologically, with contaminated food[6-8]. Some cases of 'late onset' neonatal listeriosis (presenting after the first five days of life) have been caused by nosocomial transmission[4].

Data sources

Surveillance of listeriosis in England and Wales (together with some limited reporting from Northern Ireland and the Republic of Ireland) is undertaken by the PHLS as a joint activity between the Communicable Disease Surveillance Centre (CDSC), via the national voluntary laboratory reporting scheme, and the Division of Microbiological Reagents (DMR) of the Central Public Health Laboratory. Strains of *L. monocytogenes* are sent to DMR for confirmation and subtyping. Case ascertainment has been maximised since 1983 by a regular exchange of data between CDSC and DMR[9]. This report presents the surveillance findings for 1990. On receipt of an initial case report, a brief proforma is sent by CDSC or DMR to the microbiologist, requesting further clinical and epidemiological data. Listeriosis cases are allocated to the following categories:

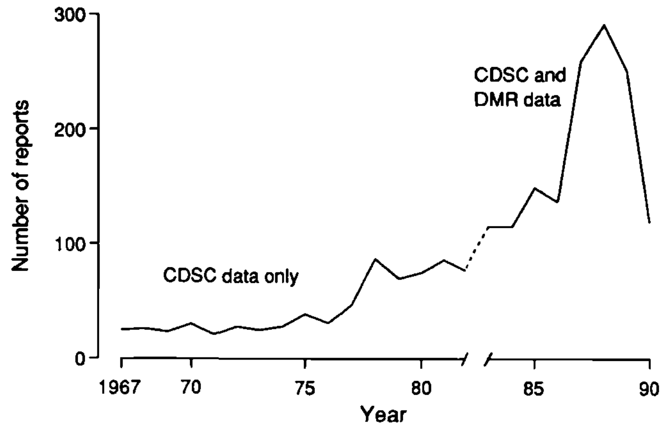
A. Pregnancy-associated: this comprises all materno-fetal and late onset neonatal cases. The former consist of cases involving maternal or fetal infection or neonatal infection up to the first five days of life (mother and fetus/infant are counted as one). The late onset neonatal cases are those aged 6-28 days.

B. Non pregnancy-associated (also called 'adult/juvenile'): any case aged over 1 month and unassociated with pregnancy. An elderly subset consists of cases aged 75 years or more in whom there is no underlying illness.

Results

A total of 118 reports of listeriosis were received from England, Wales and Northern Ireland in 1990 by CDSC and DMR. Merging the data from these two sources enhances the ascertainment of this uncommon infection. The trends in annual totals since 1967 are shown in figure 1.

Figure 1 Laboratory reports of listeriosis: England, Wales and Northern Ireland



Epidemiological features

One hundred and three of the 118 cases came from England, 12 from Wales and three from Northern Ireland (Figure 2). A further five reports, received from the Republic of Ireland, were excluded from the following analyses. The

Figure 2 Regional distribution for 1990 (figures for 1989 in parentheses)