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4. Estimating the Incidence of Foodborne *Salmonella* and the Effectiveness of Alternative Control Measures

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Estimating the Incidence of Foodborne *Salmonella* and the Effectiveness of Alternative Control Measures

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In recent years, there has been growing interest in cost-benefit analysis of alternative measures for the control of foodborne disease. However, the application of cost-benefit analysis is dependent on the availability of reliable data on the incidence of specific foodborne diseases and the effectiveness of alternative control measures. Whilst it is acknowledged that official statistics are a satisfactory indicator of general trends in the incidence of foodborne disease over time, they are an unreliable measure of the actual number of cases at any point in time. There is little published data on the effectiveness of alternative control strategies.

This chapter reports on the use of the Delphi method to estimate the incidence of foodborne *Salmonella* in the United Kingdom and the effectiveness of alternative control measures. The Delphi method is a recognized technique for reconciling differences in group judgements where there is inherent uncertainty as to the actual state of the world. In this case, the group consists of experts on foodborne *Salmonella* in the United Kingdom. The aim is to generate data which overcomes acknowledged problems with published statistics and can be employed in cost-benefit analysis of measures for the control of foodborne *Salmonella*.

Data on Incidence of Foodborne *Salmonella* in the UK

There are a number of sources of data on the incidence of foodborne infections in the UK, although none is sufficiently comprehensive to support cost-benefit analysis (Committee on Microbiological Safety of Food 1990):

1. Statutory notifications of food poisoning.
2. Reports of general practitioner consultations.
3. Informal laboratory reporting systems.
4. Outbreak reporting system.
5. Small-scale studies.

Systems of statutory notification for food poisoning operate in England and Wales, Scotland, and Northern Ireland, whereby a registered medical practitioner who becomes aware that a patient is suffering from food poisoning is required to notify a specified 'proper officer.' However, these data may be an unreliable indicator of the actual incidence of food poisoning in the UK. Although there is a statutory requirement for general practitioners to make such returns, the degree of under-reporting is known to be significant. In addition, there is no standard definition of food poisoning and consequently the data are based upon diagnoses made by general practitioners, although the cause of illness may not have been traced back to a food source (Committee on Microbiological Safety of Food 1990).

Data on statutory notifications of food poisoning for the period 1980-1994 are reported in Table 4.1. Since the mid-1980s there has been a continuous increase in statutory notifications of food poisoning throughout the UK; the total reported incidence increased from 12,763 in 1980 to 87,200 in 1994. The specific cause of food poisoning is not recorded and consequently it is not possible to ascertain the number of cases of foodborne *Salmonella*.

The Royal College of General Practitioner's Sentinel Practice Scheme provides additional data on the rate of general practitioner consultations for infectious intestinal diseases per 100,000 of the population. This scheme records diagnoses of infectious intestinal diseases by 60 general practices, covering approximately 425,000 patients (Committee on the Microbiological Safety of Food 1990). Data for newly diagnosed episodes of infectious intestinal diseases for the period 1980-88 are given in Table 4.2.

Non-statutory systems for reporting laboratory isolations of *Salmonella* operate in England and Wales, Scotland, and Northern Ireland. In England and Wales, local public health and National Health Service laboratories send isolates for precise identification and confirmation to the Public Health Laboratory Service (PHLS). In Scotland, *Salmonella* infections are reported weekly to the Communicable Diseases (Scotland) Unit and isolates sent to the Scottish *Salmonella* Reference Library for precise identification. In Northern Ireland, laboratory-confirmed infections which may be of food origin are reported by hospital laboratories to the Department of Health and Social Services (Northern Ireland), and are copied to the Communicable Disease Surveillance Centre (CDSC). Data on laboratory isolations of *Salmonella* in England and Wales, Scotland and Northern Ireland for the period 1980-94 are given in Table 4.3.

TABLE 4.1 Annual Corrected Notifications of Food Poisoning in the UK, 1980-94

Year	England and Wales	Scotland	Northern Ireland
1980	10,813	1,836	114
1981	9,936	2,934	135
1982	14,253	3,038	198
1983	17,735	2,632	128
1984	20,702	2,391	144
1985	19,242	1,967	158
1986	23,948	2,436	272
1987	29,571	2,480	423
1988	39,713	2,998	302
1989	52,557	3,197	501
1990	52,145	3,024	819
1991	52,570	2,938	636
1992	63,347	3,317	915
1993	68,587	3,255	954
1994	82,095	4,100	1,005

Source: OPCS 1993.

TABLE 4.2 Average Weekly Consultation Rates for Newly Diagnosed Episodes of Infectious Intestinal Diseases, 1980-88

Year	Average Weekly Consultation Rate Per 100,000 of Population at Risk
1980	66.7
1981	51.6
1982	47.6
1983	49.2
1984	47.0
1985	44.9
1986	45.0
1987	51.5
1988	63.4

Source: Committee on Microbiological Safety of Food 1990.

TABLE 4.3 Laboratory Reports of Fecal Isolates of *Salmonella*, 1980-93

Year	England and Wales	Scotland	Northern Ireland
1980	10,768	1,577	136
1981	10,539	2,526	131
1982	11,987	2,621	207
1983	14,240	2,288	141
1984	14,025	2,221	130
1985	11,765	1,690	115
1986	14,800	2,015	234
1987	17,552	2,286	433
1988	23,821	2,580	206
1989	24,998	2,578	205
1990	25,301	2,442	260
1991	22,659	2,330	160
1992[a]	31,352	2,992	224
1993	30,654	2,926	178
1994	30,428	2,992	275

Source: Committee on Microbiological Safety of Food 1990, Communicable Disease Surveillance Centre.

[a]On January 1, 1992 a new reporting system was implemented within the PHLS. Consequently, the figures for 1992 to 1994 are not directly comparable with previous years.

TABLE 4.4 *Salmonella* Infections in Humans in England and Wales, 1994

Serotype	# of Infections	
Salmonella enteritidis	17,370	
Phage Type 4		13,782
Other Phage Types		3,588
Salmonella typhimurium	5,523	
Salmonella virchow	2,727	
Other Serotypes	4,808	
Total	30,428	

Source: PHLS 1993.

The observed increase in human salmonellosis through the 1980s and into the 1990s was largely due to two serotypes, *Salmonella typhimurium* at the start of the 1980s and *Salmonella enteritidis* (predominately phage type 4) since 1985. Notifications have since increased to more than double those recorded during previous peaks in the 1950s and again in the 1970s (Committee on Microbiological Safety of Food 1990). By 1992, *Salmonella enteritidis* accounted for 65 percent of all human *Salmonella* infections (Table 4.4). It has been claimed that this apparent increase in human salmonellosis is largely explained by increased rates of reporting due to increased awareness of *Salmonella* among doctors and the general public. This is refuted by Sockett (1993) who claims the trend represents a real increase in incidence.

Medical officers covering environmental health and other public health professionals routinely report outbreaks of foodborne *Salmonella* to the CDSC, an 'outbreak' being defined as two or more associated cases of food poisoning. Details include the location of the outbreak, number of people infected, symptoms, suspected foods, and the method of food preparation and storage involved.

Finally, there have been a limited number of typically small-scale surveys which provide additional information on the incidence of food poisoning. In a random survey of 1,011 households in 1989, 25 percent of respondents reported that they had experienced at least one stomach upset in the previous twelve months (Wright 1989). Of those who had suffered a stomach upset, 10 percent reported suffering two upsets and 5 percent reported suffering three or more upsets.

Comparable questions were included in a survey on food hygiene conducted for the Ministry of Agriculture, Fisheries, and Food (MAFF) on a representative sample of 1,927 adults in 1987 (MAFF 1988). One in three respondents reported that they had suffered a stomach upset in the past six months. However, only 4 percent of respondents claimed to have suffered an upset caused by something eaten or food poisoning in the previous six months.

In 1993, a nation-wide survey of 1,943 adults was conducted by the Food and Drink Federation and the Institution of Environmental Health Officers. Of those questioned, 6 percent claimed that they had suffered from food poisoning in the previous year (FDF and IEHO 1993). In comparable studies in 1994 and 1995, 5 and 7 percent of respondents, respectively, claimed that they had suffered from food poisoning in the previous year (FDF and IEHO 1994, FDF, IEHO, and REHIS 1995).

It is generally accepted that published statistics on the annual cases of food poisoning and *Salmonella* infections underestimate the true incidence as a consequence of imperfections in the system of reporting (McCormick 1993, Committee on Microbiological Safety of Food 1990, House of Commons 1989). For example an infected person may not seek medical advice or a general practitioner may fail to identify a disease as food poisoning and take a stool sample. In a recent survey of public attitudes to diarrhea, only 8 percent of respondents claimed they would consult a doctor immediately if they contracted diarrhea, while 56 percent would consult a doctor after one to two days (Philipp et al. 1993). Consequently, many cases of food poisoning are neither diagnosed nor reported.

It is not possible to determine the magnitude by which official statistics under-report the incidence of human salmonellosis with any degree of certainty. For example, estimates of under-reporting given as evidence to the Agriculture Select Committee's investigation of *Salmonella* in eggs, ranged from a factor of ten to a factor of 100 (House of Commons 1989).

There is clearly considerable uncertainty over the actual incidence of human salmonellosis in the UK, largely due to differing views on the level of under-reporting embodied in official statistics. This study employs the Delphi method in a structured attempt to reconcile such differences in expert opinion and provide more reliable estimates of the incidence of foodborne salmonellosis.

The Delphi Method

The Delphi technique is a method of eliciting and refining group judgements. It provides a mechanism for aggregating the judgements of a number of individuals in order to improve the quality of estimates given inherent uncertainty as to the actual state of the world. The Delphi technique is essentially a series of questionnaires. Initial questions ask experts to consider a series of broad issues. Each subsequent questionnaire builds upon responses to the preceding questionnaire. The process ceases once consensus has been approached among participants (Dalkey 1969). An excellent review of the Delphi technique is provided by Linstone and Turoff (1975).

The rationale behind this procedure is that "two heads are better than one" when the issue is one where exact knowledge is not available at the present time. According to the founder of the method, "it is logical that if you properly combine the judgement of a large number of individuals, you have a better chance of getting closer to the truth" (Dalkey and Helmer 1963, Helmer 1969). This is best explained through an example. Consider the situation where the judgement required is a numerical estimate. Given a group of indistinguishable experts, and consequently no way of asserting that one expert is more reliable than another, is it better to consult one expert at random and accept his/her individual response, or to take some statistical aggregate of the opinions of the group? It can be shown that, independent of the distribution of responses and the position of the true answer, the median response will be as close to the true answer as responses given by 50 percent of the group. Further, if the range of responses provided by the group includes the true answer, then the median response will be at least as close to the true answer as responses given by 50 percent of the group. This demonstrates the greater efficiency of the Delphi method for deriving numerical estimates on the basis of expert opinion.

A frequently observed and uncomfortable aspect of expert opinion is that experts with seemingly equivalent credentials are likely to give quite different responses to the same question. A major advantage of group techniques such as the Delphi method is that this inherent diversity is replaced by a single representative opinion.[2] However, this should not be taken as a suggestion that the median response should be considered in isolation, ignoring the full distribution of answers and therefore the uncertainty inherent in the estimates obtained.

The Delphi method has three key characteristics designed to minimize the biasing effects of dominant individuals, irrelevant communications, and of group pressure towards conformity (Dalkey 1969):

1. Anonymous responses: Opinions of respondents are obtained through a series of formal questionnaires.
2. Iteration and controlled feedback: Iteration is effected systematically with carefully controlled feedback between rounds whereby a summary of the results of the previous round are communicated to each participant.
3. Statistical group response: Group opinion is defined as an appropriate aggregate of individual opinions in the final round. This reduces pressure for conformity within the group and, consequently, at the end of the exercise a significant spread in individual opinions may remain. The

use of a statistical group response also ensures that the opinions of all members of the group are represented in the final response.

There are a number of benefits of the Delphi method which confirm its suitability for the present study (Dalkey 1969):

1. It is a rapid and relatively efficient method for consulting expert opinion.
2. The effort required of each respondent is less than the majority of alternative methods, for example attendance at a meeting.
3. Properly managed, the Delphi exercise can create a highly stimulating environment for respondents. Within a mutually self-respecting group of experts, the feedback can be novel and interesting.
4. Anonymity and group response foster a sharing of responsibility that overcomes respondent inhibition.
5. The use of systematic procedures lends a degree of objectivity to the outcomes which is reassuring to users of the final data.

However, there have been certain criticisms of the Delphi method which should be kept in mind when interpreting the results from the current study. For example, it is claimed that the Delphi method lacks the stimulation of face-to-face communication leading to a feeling of detachment from the problem-solving effort and creating communication and interpretation difficulties among respondents (Delbecq et al. 1975). In addition, the quality of responses is highly sensitive to the nature of the monitoring team. As a result of the central position of the monitoring team within the Delphi process, there is a potential for biasing of results and suppression of extreme responses through the imposition of an over-restrictive procedure.

The Delphi process has become recognized as a standard procedure for eliciting expert opinion to bridge gaps or inherent uncertainties in available data. Consequently, the technique has been applied to a wide variety of problems including the evaluation of drug abuse policy, factors affecting quality of life, defense, forecasting production, solutions to societal problems, and forecasts of technological developments (for a review see Linstone and Turoff 1975).

Delphi Study of Foodborne *Salmonella*

Given the inherent complexity of the concepts and issues associated with the incidence and control of foodborne *Salmonella*, the Delphi survey was divided into two stages: 1) small-scale workshop and 2) main Delphi survey. To aid the design of the Delphi survey a workshop comprised of seven experts on foodborne *Salmonella* was held at the end of May 1993. At the workshop each component of the survey was discussed in a systematic manner using the nominal group technique (see, for example, Morgan 1989). Of particular interest was the specific wording of the questions in each round of the survey, with the aim of minimizing the complexity of each task while avoiding ambiguity. For example it was observed that most experts find it easier to estimate the incidence of foodborne Salmonella if the task is split into two components: 1) annual number of cases of human salmonellosis and 2) proportion of cases of human salmonellosis in which food is the mode of transmission.

A total of 62 experts on foodborne *Salmonella* were contacted and invited to participate in the Delphi survey. The list of experts was compiled in consultation with participants at the workshop. A total of 42 experts agreed to be sent the first-round questionnaire. The main reason given for not agreeing to take part in the first round of the survey was lack of specific expertise on foodborne *Salmonella*. In total there were five rounds of the Delphi survey over a period of seven months from July

1993 to January 1994, although most questions were subject to only three iterations.[3] The number of respondents in round one of the study was 33 (79 percent response) and in subsequent rounds was 32 (76 percent response).

In total, five questions were presented to the panel of experts. The first three questions were inter-related and included in each of the first three rounds of the Delphi survey. The first question in the survey asked respondents to estimate the annual incidence of human salmonellosis:

> What would you estimate to be the **total** number of persons ill due to infection with non-typhoid *Salmonella* in the UK from all sources (food and non-food), over the course of one year?

The second question asked respondents to estimate the proportion of cases of human salmonellosis in which food is the mode of transmission:

> Given your estimate [above] of the total incidence of all types of human infection with non-*typhi Salmonella* from all sources, what would you estimate to be the proportion of total infections with non-*typhi Salmonella* acquired in the UK in which **food** is the mode of transmission?

The third question asked respondents to estimate the proportion of cases of foodborne *Salmonella* in which particular foods are the mode of transmission:

> Given your estimate [above] of the proportion of the total incidence of human infection with non-*typhi Salmonella* where food is the mode of transmission, what proportion would you estimate is transmitted by each of the following foods?

Respondents were presented with a list of foods which had been identified as potentially significant modes of transmission for non-*typhi Salmonella* in the workshop. An 'others' category was included to permit respondents to indicate additional foods.

For each question, respondents were asked to provide a few brief comments on how they arrived at their initial estimate and to indicate any difficulties they had experienced. Two subsequent iterations repeated these questions, reporting the median, minimum, and maximum response by the total sample in the previous round and inviting respondents to revise their existing estimate.[4]

The final question considered the control strategies available to reduce the incidence of foodborne non-*typhi Salmonella* in the UK. In the first round, respondents were simply asked to provide a list of strategies available for the control of foodborne *Salmonella*. In the second round, a list of control strategies based on the group responses in round one was presented and respondents asked to comment, indicating any additions or deletions and where individual items overlapped. In the third round, a refined list was presented and respondents asked:

> Taking each control strategy in turn, consider how effective it would be at reducing the total incidence of foodborne non-*typhi Salmonella* in the UK? In making your assessment assume that:
>
> a. Each control measure is implemented unilaterally (this obviously ignores any synergy between measures implemented as a part of a series of control strategies).
> b. Each control measure is implemented across the supply chain (this obviously ignores any problems in implementing each control strategy).

Two subsequent iterations repeated this question, reporting the median, minimum, and maximum response by the total sample in the previous round and inviting respondents to revise their existing estimate.

Estimated Annual Incidence of Non-*typhi Salmonella*

The estimated annual incidence of human non-*typhi Salmonella* in each round of the Delphi study is reported in Table 4.5. Over the three rounds of the study, the respondents giving the lowest estimates progressively revised their estimates upwards, but there was no comparable revision downwards by respondents giving the highest estimates. Consequently, the median increased from 500,000 to 600,000 cases per annum. As expected, the standard deviation within the sample diminished over the three rounds of the study, although not significantly so.

The number of respondents revising their estimates between round one and round two of the study was 17 (53 percent) and between round two and round three of the study was 10 (31 percent). This was typical of responses to the Delphi survey as a whole. Firstly, the number of respondents revising their estimates diminished as the study progressed, indicating a growth in confidence on the part of respondents in their own estimates. Secondly, apart from those giving extreme estimates, a significant proportion of respondents did not revise their original response through the three rounds of the survey. Consequently, the Delphi survey was only partially successful at drawing the sample towards a consensus, reflecting the considerable uncertainty among experts over the actual incidence of foodborne salmonellosis.

At first sight, the wide range between the lowest and highest estimates raises doubts about the reliability of the estimates (Figure 4.1). However, 75 percent of the sample gave final estimates of 1,000,000 or less, while 95 percent of the sample produced final estimates of 1,500,000 or less. Consequently, the distribution is positively skewed, the mean (733,437) being pulled upwards by a small number of extremely high estimates.[5]

Respondents were asked to comment on how they arrived at their initial estimate of the annual incidence of human salmonellosis (Table 4.6). The majority of respondents reported that their estimate was based on published data on laboratory confirmed cases, adding a factor to reflect under-reporting by individuals and/or general practitioners. A smaller group of respondents reported the use of incidence data from the United States or the results from surveys and small-scale studies.

A number of problems were reported by respondents in estimating the annual incidence of human salmonellosis in the UK including: 1) problems estimating the proportion of cases infected abroad; 2) incompatibility of data sets, in particular data on laboratory-confirmed cases from England and Wales, Scotland, and Northern Ireland; 3) limitations of laboratory detection procedures; and 4) limitations of extrapolating from 'old' data. Clearly, a number of respondents faced considerable difficulty in estimating the incidence of human salmonellosis in the UK which might account for the extreme responses at both the higher and lower end of the distribution.

TABLE 4.5 Estimated Total Incidence of Human Salmonellosis in the UK

Round	Number of Respondents	Median	Minimum	Maximum	Standard Deviation
1	33	500,000	90,000	3,000,000	567,288
2	32	500,000	150,000	3,000,000	589,218
3	32	600,000	170,000	3,000,000	520,214

FIGURE 4.1 Quartile Distribution of Estimated Annual Incidence of Human Non-*typhi* Salmonellosis in the UK

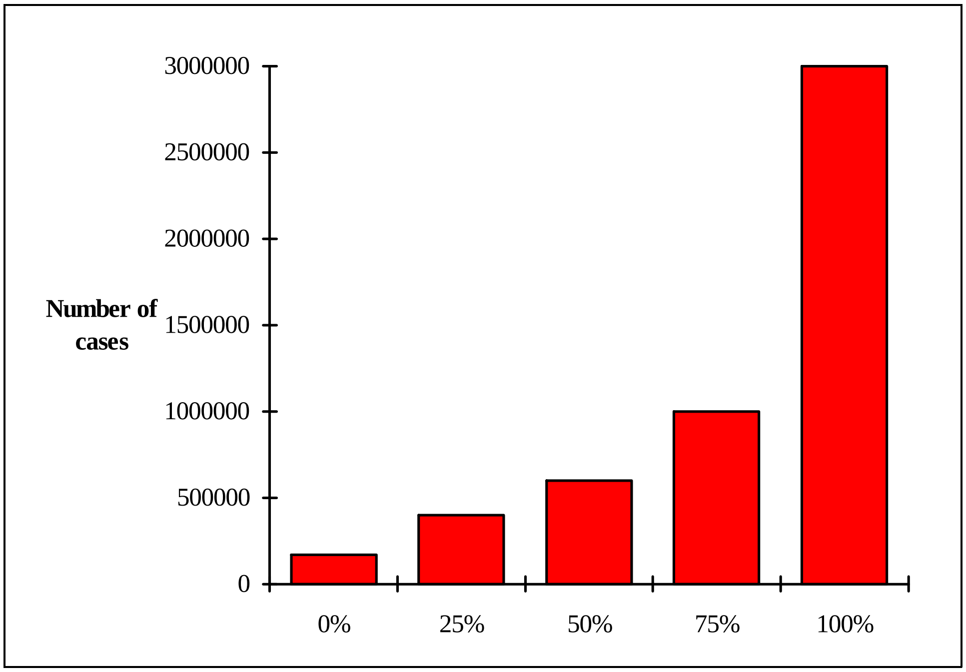


TABLE 4.6 Reported Method of Estimating Total Annual Incidence of Human Salmonellosis

Methods of Estimation	Number of Respondents[a]	
Laboratory confirmed cases plus factor	26	(78.8 %)
Factor reflects under-reporting by general practitioners	4	(12.1 %)
Factor reflects under-reporting by patients	7	(21.2 %)
Factor reflects general under-reporting	7	(21.2 %)
Data on incidence in the United States	3	(9.1 %)
Data from surveys or small specific studies	2	(6.1 %)
Own experience plus factor	2	(6.1 %)
Guess	1	(3.0 %)
No method specified	4	(12.1 %)

[a]Some respondents specified more than one method and, consequently, percentages add to more than 100 percent.

Estimated Incidence of Foodborne Non-*typhi Salmonella*

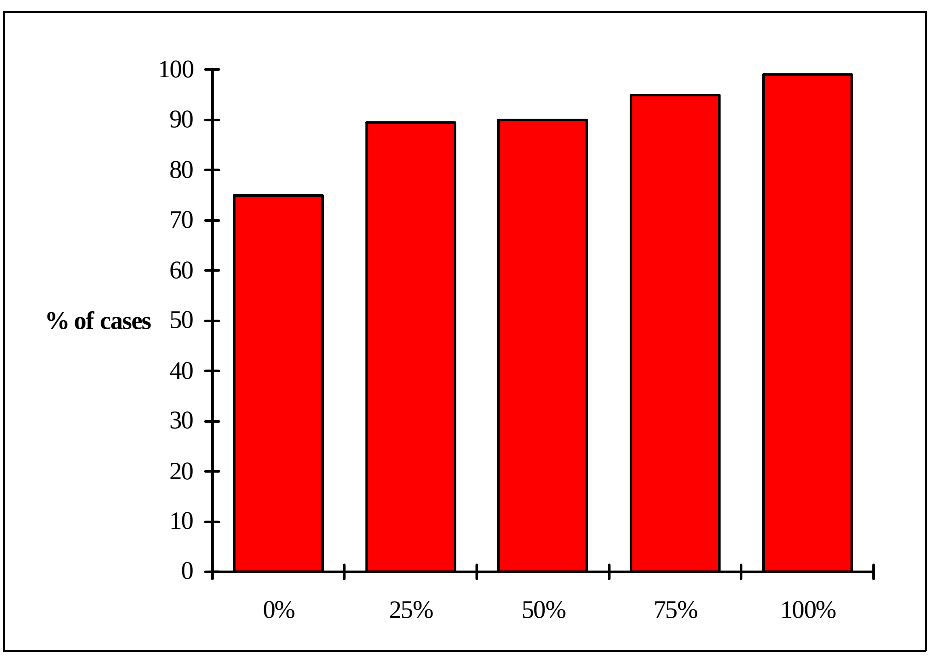
The investigation of foodborne illness to determine the vehicle and route of infection is both complex and time-consuming. Consequently, although it is generally acknowledged that food is implicated in the vast majority of cases of human salmonellosis, reliable estimates of the proportion of cases in which food is the mode of transmission are not readily available. For example, estimates of the proportion of general outbreaks in which a food vehicle is identified range from 56 percent (ACMSF 1993) to 87 percent (Palmer 1992).

The second question in the Delphi survey asked respondents to estimate the proportion of cases of human salmonellosis in which food is the mode of transmission. Although the median response was 90 percent throughout the survey, the standard deviation declined significantly as extreme estimates, and in particular very low estimates, were revised (Table 4.7). Consequently by the end of the third round, 75 percent of respondents estimated the proportion of cases of human salmonellosis in which food is the mode of transmission to be in excess of 90 percent (Figure 4.2).

TABLE 4.7 Estimated Proportion of Cases of Human Salmonellosis in Which Food is the Vehicle of Infection

Round	Minimum (%)	Median (%)	Maximum (%)	Standard Deviation
1	66	90	100	8.65
2	75	90	99	6.88
3	75	90	99	6.49

FIGURE 4.2 Quartile Distribution of Estimated Proportion of Cases of Human Salmonellosis in Which Food is the Mode of Transmission



The number of respondents revising their estimate between round one and round two of the survey was 15 (47 percent) and between round two and round three was 10 (31 percent). In addition, the magnitude of individual revisions declined, indicating a growth in confidence on the part of respondents in their own estimate.

Now that the proportion of cases in which food is the mode of transmission has been established, it is natural to examine the role of individual food products. However, there is considerably less published data on the role of specific foods as modes of transmission than on food as a whole. Data on reported food vehicles in general outbreaks of *Salmonella* in the UK are available from the Public Health Laboratory Service (PHLS) (Table 4.8). However, these data do not provide any information on the role of food as a vehicle in sporadic cases. Further, even in the case of outbreak, a significant proportion of investigations fail to confirm a food as the vehicle of transmission.

Additional information on the role of individual food products as a vehicle of infection is provided by specific surveys or studies. For example, the MAFF Food Hygiene Survey in 1987 asked respondents who reported that they had suffered from a stomach upset in the previous six months due to something that had been eaten, to indicate which particular food item they thought was responsible for their illness (Table 4.9). The food products most frequently cited were poultry, pork, beef, and shellfish, although in 19 percent of cases respondents reported that they did not know which food had caused their stomach upset.

TABLE 4.8 Reported Food Vehicles in General Outbreaks of *Salmonella* Infection, 1989-91

Type of Food	Number of Outbreaks	%
Chicken	23	5.9
Turkey	21	5.3
Beef	7	1.8
Pork or ham	5	1.3
Cold meats	7	1.8
Other meats or pies	24	6.1
Gravy or sauces	1	0.3
Milk	3	0.8
Other dairy products	1	0.3
Eggs	50	12.7
Vegetables or spices	1	0.3
Bakery products	7	1.8
Sweets or puddings	21	5.3
Mixed foods	47	12.0
Other/not stated	174	44.4
TOTAL	392	55.7[a]

Source: Sockett et al. 1993.
[a]Does not total 100 percent due to rounding.

TABLE 4.9 Reported Food Thought to Have Been Responsible for Stomach Upsets in the MAFF Food Hygiene Survey, 1988

Food Items Suspected	% of Cases
Poultry	18
Pork	11
Beef	9
Shellfish	9
Canned fish	5
Meat pies	3
Frozen pre-packed meals	2
Lamb	2
Stews	2
Vegetables	2
Milk	2
Home-made soups	1
Other dairy products	1
Other items	26
Don't know	19

Source: MAFF 1988.

The third question in the Delphi survey invited respondents to estimate the proportion of cases of foodborne *Salmonella* in which particular foods are the vehicle of infection. As might be expected, poultry and poultry products and eggs and egg products were judged to be the most important vehicles of infection for non-*typhi* foodborne *Salmonella* (Table 4.10). However even after three rounds of the survey, there remained significant disagreement between experts on the role of specific foods. For example, the estimated proportion of cases where poultry and poultry products are the mode of transmission ranged from 28 to 75 percent.

The implied annual incidence of foodborne *Salmonella* can be computed from each respondent's estimate of the total incidence of human non-*typhi* salmonellosis and the proportion of cases in which food is the mode of transmission:

(1) $$S_i^f = S_i^t \times F_i$$

where:

S_i^f = implied annual incidence of foodborne *Salmonella* for respondent i.

S_i^t = estimated total incidence of human non-*typhi Salmonella* for respondent i.

F_i = estimated proportion of cases of non-*typhi Salmonella* in which food is the mode of transmission for respondent i.

The estimated annual incidence of non-*typhi Salmonella* and the estimated proportion of cases where food is the vehicle of infection are negatively correlated. Consequently, the distribution of implied annual incidence of foodborne non-*typhi Salmonella* differs from the distribution of estimated annual

TABLE 4.10 Final Estimates of the Percent of Cases of Foodborne *Salmonella* in Which Particular Foods Are the Vehicle of Infection

Food Group	Minimum (%)	Median (%)	Maximum (%)	Standard Deviation
Pork and products	1	5	12	2.6
Poultry and products	28	50	75	10.9
Beef and products	0	5	8	2.3
Lamb/mutton and products	0	1	5	1.1
Meat pies and pasties	0	5	20	4.6
Eggs and products	5	26	60	10.2
Milk	0	2	5	1.3
Cheese and products	0	1	2	0.5
Fruit/vegetables and products	0	1	4	0.9
Seafood and products	0	2	5	1.0
Spices	0	0.5	2	0.5
Chocolate	0	0.5	1.5	0.4
Others	0	1	9	1.9

incidence of non-*typhi Salmonella* (Figure 4.3). Although the implied annual incidence of foodborne *Salmonella* ranged from 164,900 to 2,670,000, 90 percent of estimates were less than 950,000 and consequently the median was only 537,000.

The implied annual incidence of foodborne *Salmonella* where particular foods are the vehicle of infection can be computed from the estimated annual incidence of foodborne *Salmonella* and the proportion of cases where particular foods are the mode of transmission:

(2) $$S_{ij}^{f} = S_{i}^{f} \text{ x } V_{ij}$$

where:

S_{ij}^{f} = implied annual incidence of foodborne *Salmonella* where food j is the mode of transmission for respondent i.

S_{i}^{f} = implied annual incidence of foodborne *Salmonella* for respondent i.

V_{ij} = estimated proportion of cases of foodborne *Salmonella* in which food j is the mode of transmission for respondent i.

Table 4.11 reports the minimum, median, and maximum estimated annual incidence of foodborne *Salmonella* in which particular foods are the mode of transmission. In the vast majority of cases either poultry and poultry products or eggs and egg products are the mode of transmission.

FIGURE 4.3 Quartile Distribution of Implied Annual Incidence of Foodborne Non-*typhi* Salmonellosis in the UK

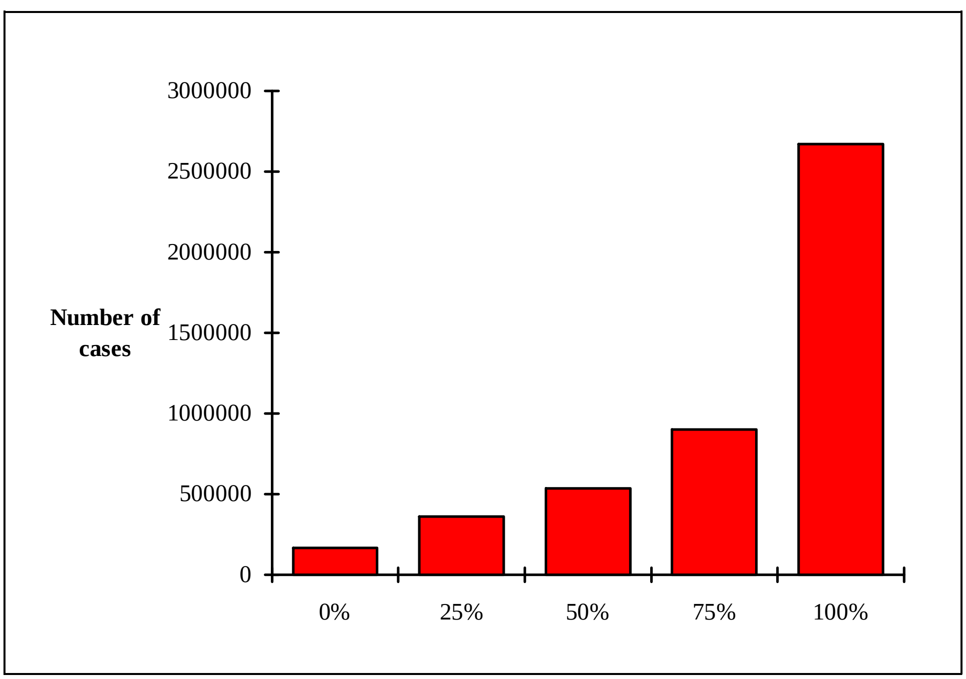


TABLE 4.11 Estimated Annual Incidence of Foodborne *Salmonella* in Which Particular Foods Are the Vehicle of Infection

Food Group	Minimum	Median	Maximum
Pork and products	3,600	29,700	82,770
Poultry and products	82,450	270,000	1,335,000
Beef and products	0	28,800	67,500
Lamb/mutton and products	0	7,125	28,500
Meat pies and pasties	0	22,500	297,000
Eggs and products	45,000	123,150	667,500
Milk	0	9,225	66,750
Cheese and products	0	4,150	26,700
Fruit/vegetables and products	0	4,500	26,700
Seafood and products	0	4,750	40,500
Spices	0	3,375	18,000
Chocolate	0	2063	10,680
Others	0	4,750	53,400

Effectiveness of Alternative Control Measures

The final question in the Delphi survey considered the effectiveness of alternative measures for the control of foodborne *Salmonella* (Table 4.12). Effectiveness is defined as the percentage reduction in the annual incidence of foodborne non-*typhi Salmonella* when the control measure is applied unilaterally across the food supply chain, ignoring any implementation problems.

The most effective strategy for the control of foodborne *Salmonella* is judged to be food irradiation, followed by mandatory implementation of HACCP. Strategies judged to be largely ineffective include the use of pasteurized eggs and banning the sale of unpasteurized milk. However, even after three rounds of the Delphi survey there remained considerable disagreement over the effectiveness of individual control measures. For example, the estimated effectiveness of food irradiation ranged from 0 to 80 percent, although 75 percent of respondents gave estimates in excess of 30 percent (Figure 4.4).

The median estimated effectiveness of each control measure was generally low, although potential implementation problems were ignored. This reflects the considerable synergy between individual control measures when they are implemented simultaneously, suggesting this is the most effective approach to the control of foodborne *Salmonella*.

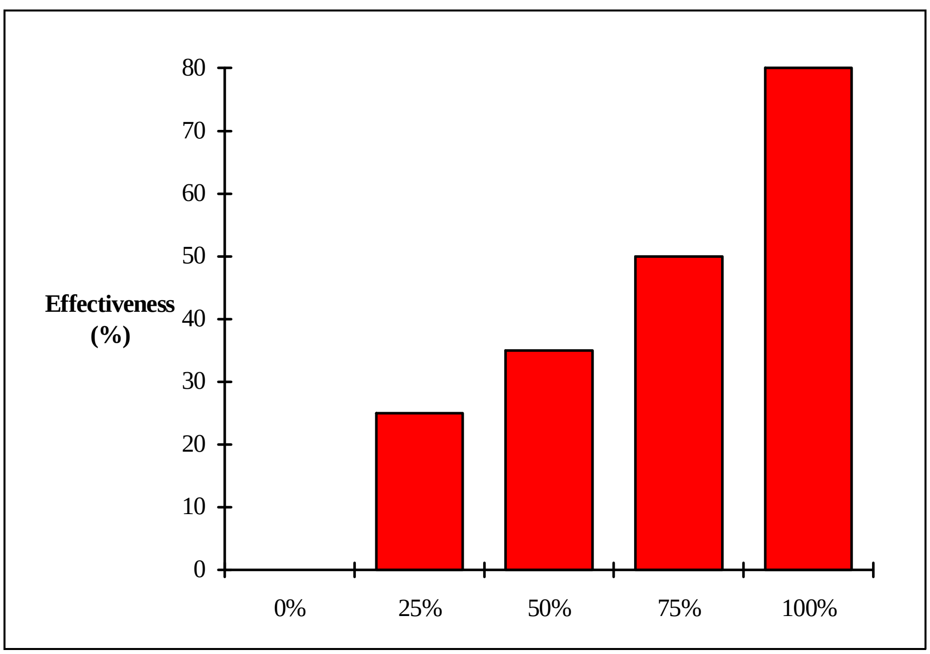
Conclusions

Although the Delphi technique was only partially successful at reducing the level of disagreement between experts in the case of foodborne *Salmonella*, it does have a potentially valuable role to play in the economic assessment of foodborne disease. On the one hand, the median response to the final round of the survey provides a good summary measure of expert opinion in an area which is characterized by great uncertainty. On the other hand, the spread of responses provides a good indication of the range within which we can expect to find the actual state of the world.

TABLE 4.12 Estimated Effectiveness of Control Strategies in Third Round of Delphi Study

Control Measure	Reduction in Total Incidence of Foodborne Non-*typhi Salmonella* (%)		
	Minimum	Median	Maximum
Training of food handlers	2	20	50
Consumer information/education	3.5	20	60
Food irradiation	0	35	80
Ban unpasteurized milk	0.5	3	60
Improved husbandry practices	1.5	10	80
Reduced contamination of feed, breeding stock, etc.	3.5	20	80
Competitive exclusion	5	20	50
Animal vaccines	2	20	50
Licensing of food premises	0	10	20
Improved reporting and investigation of outbreaks	8	20	55
Improved poultry processing practices	1	10	20
Improved slaughter and dressing techniques	2	10	60
Cold chain distribution of eggs	0	10	20
Mandatory HACCP	5	25	80
Use of pasteurized eggs	5	5	25

FIGURE 4.4 Quartile Distribution of Estimated Effectiveness of Irradiation for the Control of Foodborne *Salmonella*



The Delphi technique suffers from certain problems and limitations which should be kept in mind when utilizing the technique. Firstly, the results from a Delphi survey are only valid if the panel of experts reflects the full range of opinions within the relevant subject area. Secondly, because of the central role of the researcher in monitoring responses and reporting them to subsequent rounds of the survey, there is the potential for biasing of results, in particular the suppression of extreme responses in an attempt to force respondents to some form of consensus. This emphasizes the need for the study to be carefully designed, as with any survey method, with guidance from members of the expert community actually being surveyed.

Notes

[1]Spencer Henson is a Lecturer in the Department of Agricultural Economics and Management, University of Reading, Reading, UK.

[2]This is not of the same value if clearly defined groups of experts produce distinct and highly different answers to the same question.

[3]A copy of each questionnaire is available on request.

[4]A fourth question, not reported here, asked respondents to estimate the proportion of cases which result in mild, moderate, and severe health effects.

[5]Two respondents gave estimates of 3,000,000 with the next highest estimate being 2,000,000.

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