FOOD RESEARCH INSTITUTE
University of Wisconsin-Madison

FRI FOOD SAFETY REVIEWS

White Paper on Human Illness Caused by *Salmonella* from all Food and Non-Food Vectors, Update 2013

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http://fri.wisc.edu/docs/pdf/FRI_Brief_updateSalmonellaHumanIllness_April2013.pdf
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INTRODUCTION

Salmonella spp. have been recognized as human and animal pathogens for over a century. They are estimated to cause about 1.03 million non-typhoidal infections in humans per year in the U.S., with approximately 378 deaths and over 19,000 people requiring hospitalization. About 96% of these cases are believed to be foodborne (*124*). Additionally, between 285 and 467 cases of typhoid fever occurred yearly during the past 5 years in the U.S. (*39*). According to 2012 data from FoodNet, the incidence of salmonellosis has not diminished significantly over the past five years. In fact, the incidence in 2012 was 16.4/100,000 population compared to 14.9/100,000 in 2007 (*41*). This is significantly in excess of the Healthy People 2010 and 2020 objectives of 11.4/100,000 and 6.8/100,000, respectively (*147*: CDC Salmonella infections).

Approximately 2,500 *Salmonella* serotypes have been described, but 65% of the serotyped isolates from human cases in the U.S. in 2011 belonged to just six serotypes (Enteritidis, Typhimurium, Newport, Javiana, I 4,[5],12:I:-, and Muenchen) (*148*: CDC serotypes). With the exception of typhoid and paratyphoid fevers, cases of salmonellosis generally involve mild to moderate symptoms of gastroenteritis lasting for about 5 days. However, infants, the elderly, and the immunocompromised may contract more severe infections. Salmonellae may also cause urinary tract infections and sometimes migrate out of the intestine and cause meningitis and reactive arthritis (*10;112*). Although salmonellosis is typically not fatal, the large number of cases make it a high profile disease with a significant estimated economic cost of at least $4 billion annually in the U.S. (*125*).

Salmonellae naturally live in the intestines of humans and other animals; therefore, fecal material is usually the ultimate source of these bacteria. Salmonellae are also present in the lymph nodes of some healthy cattle and other animals and this may be a source of *Salmonella* contamination of ground meat (*76;89;91*).

Recent outbreaks have been traced to beef, turkey, and chicken. But even though consumers frequently think of salmonellae as associated with poultry and other meats, not all animal sources of *Salmonella* spp. are farm animals. Persons handling baby poultry, hedgehogs, turtles, feeder rodents, and dog food have become infected with *Salmonella* in 2011–13 (*61;131;142*). In addition, a number of recent outbreaks have been traced to plant-based foods, including cucumbers, peanut butter, cantaloupe, mangoes, papayas, and pine nuts. Large waterborne outbreaks of typhoid fever continue to sicken numerous people in developing countries, such as the outbreak in Zimbabwe in 2011–2012.

Increasing numbers of *Salmonella* isolates are resistant to one or more antibiotics, and this may increase the difficulty and cost of treating seriously ill patients. In the 1990s, S. Typhimurium DT104, resistant to five antibiotics (ampicillin, chloramphenicol, streptomycin, sulfonamides, and tetracycline), emerged in Europe and has since spread to many other countries. Data from NARMS from 2010 indicated that S. Typhimurium and S. Newport were the most frequently detected multidrug-resistant serovars in foodborne outbreaks but other serovars also include multiresistant strains as well as isolates resistant to just one or two antibiotics (*31*).

This update to the 2009 FRI white paper (*149*: FRI 2009 Salmonella White Paper) will summarize epidemiological data on the relationships between food and non-food vehicles and vectors and human illnesses caused by *Salmonella* published in the past 5 years and compare data published since 2008 with that presented in the previous white paper for AMIF on vehicles associated with human illness caused by *Salmonella*. Such data may offer some insight on the successes of different control strategies and remaining challenges for decreasing *Salmonella* infections.

EPIDEMIOLOGY OF *SALMONELLA* SPP.

Outbreaks and Cases

Recent FoodNet data continue to demonstrate that a majority (about 95%) of cases of salmonellosis are not linked to outbreaks but that over 85% are foodborne, with smaller percentages attributed to person-to-person or animal contact or to other/unknown vehicles. CDC estimates that the true incidence of salmonellosis is at least 29-fold greater than the number of reported cases because most people experience moderate symptoms and do not seek medical care. Approximately 1.03 million non-typhoidal *Salmonella* infections were estimated to occur in 2011 in the U.S., with approximately 378 deaths and over 19,000 people hospitalized. In terms of the number of cases of foodborne illness, only norovirus exceeds *Salmonella*. *Campylobacter* and *Clostridium perfringens* rank third and fourth, with somewhat under 1,000,000 cases/year (*124*).

Although most *Salmonella* infections cause symptoms for only about 5 days, some are more severe and are associated with hyperinfectious, hypervirulent strains. These strains produce more toxin and

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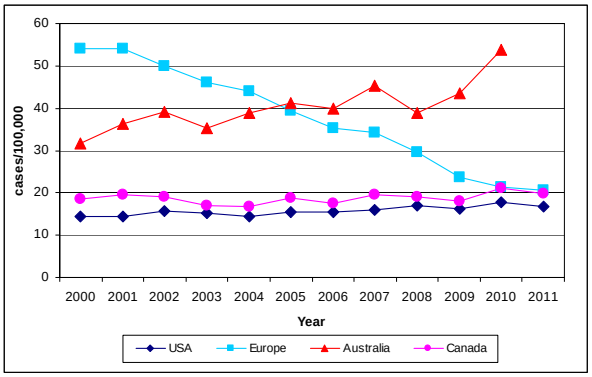
apparently secrete factors that interfere with the host animal's immune response (*80*). Salmonellae may also cause adverse effects persisting long after gastro-intestinal symptoms have resolved. Follow-up of over 140 Spanish cases sickened by S. Hadar from roast chicken found that 16% of them experienced reactive arthritis or other musculoskeletal symptoms three months after the outbreak (*10*).

A recent analysis of health costs of foodborne infections estimated that the average cost of a case of salmonellosis using a basic cost-of-illness model was $4,312 (in 2010 USD), leading to a total annual cost of $4.43 billion. This is the highest annual cost for any known foodborne pathogen. Norovirus causes more cases of illness but the cost per case is much lower, with an estimated total annual cost of $2.896 billion. Estimated average health costs for cases caused by some other pathogens, including *C. botulinum*, *L. monocytogenes*, and *V. vulnificus*, are much higher—in excess of $1.2 million/case but there is a much lower annual number of cases: 55, 1591, and 96, respectively—so that annual costs are much less than for *Salmonella*. The estimates from these basic models include costs for medical care (2008 estimates for care), productivity losses, and mortality and are likely an underestimate for actual costs in 2013. An enhanced model that includes costs for pain and suffering estimates higher annual costs, particularly for pathogens like *Salmonella* and *Campylobacter* that cause painful sequelae such as reactive arthritis (*125*).

Models for estimating health costs do not include all the economic costs of foodborne illness. Public health agencies tracking outbreaks and restaurants and industries associated with contaminated food also suffer significant losses. An assessment of economic costs associated with the waterborne outbreak of salmonellosis in Alamosa, Colorado in 2008 estimated that it cost residents and businesses $1.5 million. This number increased to $2.6 million when outbreak costs to local, state, and non-governmental agencies and schools were included (*3*).

Data from the EU on outbreaks of foodborne disease in 2011 indicated that *Salmonella* was the most commonly identified pathogen, associated with 1,501 outbreaks or 26.6% of the total. This is a 6.4% decrease in number of outbreaks since the previous year and correlates with a 5.4% decline in human salmonellosis cases from 2010 to a total of 97,897 cases reported in 2011. Only 56 fatalities were reported (*55*). Data from the European Union, Australia, Canada, and the CDC in the U.S. from 2000 to 2011 demonstrate a marked decrease in incidence of salmonellosis in Europe, an increase in Australia, and little change in incidence in Canada and the U.S. (**Figure 1**) (*8;55;114–116;120–122*). This appears to continue the trends reported in the previous FRI white paper (*149*). The significant decline in salmonellosis in Europe appears to be largely a result the decline in S. Enteritidis with the adoption of more stringent preventive measures by poultry and egg producers (*111*). In comparing different geographical areas, differences in the relative incidence rates may reflect more or less intensive surveillance systems. Australia instituted a more comprehensive national surveillance system in 2000 and this may partially account for the observed increase in salmonellosis. The European Centre for Disease Prevention and Control reports that despite the overall decreasing trend for salmonellosis in Europe over the last ten years, this trend is not the same for all countries.

Figure 1. Incidence of reported cases of salmonellosis, 2000–2001.



Over 450 outbreaks of salmonellosis in the U.S. and other countries, occurring in 2008–2013, were described in journal articles or government websites and are tabulated chronologically in the Appendix (*following p. 32*). This list does not include all of the waterborne outbreaks of typhoid fever that occurred in developing countries nor all of the hundred or so outbreaks in more developed countries that were not associated with a definite or probable vehicle. There are also some outbreaks listed in the latest report from ECDC (*55*) that are not included because they were published just shortly before this paper was completed.

Large outbreaks of salmonellosis during the past ten years, with greater than 127 cases, are presented in **Table 1** (*p. 20*). The largest reported outbreak was a water-borne typhoid fever outbreak in Zimbabwe in 2012. Of the next six outbreaks, vehicles included eggs, smoked salmon, peanut butter, chicken, turkey, and watermelon. Other large outbreaks were linked to beef burgers in France, feeder mice (fed to pet reptiles), raw tuna, pork sausage, cantaloupe, and sprouts.

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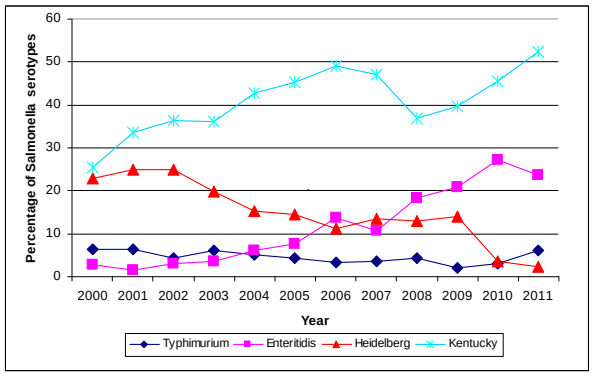
Compared to the previous FRI white paper (*149*), this review does not include many large outbreaks in Japan involving thousands of cases. Not all public health information from Japan is available in English so there may be some recent events that have not been well publicized.

Figure 2. Changes in percent distribution of the four most common *Salmonella* serotypes in broiler chickens.



Reservoirs of Salmonellae

Farm Animals

Cattle, pigs, and poultry are known to harbor salmonellae that cause human infections, and these serotypes usually do not cause symptoms in the animals. **Table 2** lists the most common serotypes detected in farm animals in Europe and the U.S. and in ground meat from the U.S. The relative importance of different serotypes in chickens has changed somewhat during the past five years in the U.S. (**Figure 2**). S. Enteritidis and S. Kentucky account for increasing percentages of isolates while the importance of S. Heidelberg appears to be decreasing. Most member states in the European Union have seen a continuing decline in S. Enteritidis and S. Typhimurium in poultry during the past 10 years. If manure from animals harboring salmonellae is used to fertilize fields or washes into surface waters or farm fields used to grow vegetables, salmonellae from the animals may contaminate fresh produce.

Pets

Turtles are the pets most commonly associated with salmonellosis although many animals may be transient carriers of *Salmonella*. In the past five years, turtles, lizards, snakes, aquatic frogs, baby poultry, and hedgehogs were identified as causes of outbreaks and cases. An Australian survey of 210 captive and 294 wild reptiles found that 47% of captive reptiles and 28% of wild animals were shedding salmonellae when tested (*126*). *Salmonella* shedding by snakes used in a public outreach program was tested weekly for 10 weeks. Eleven of 12 snakes tested positive at least once and 7 snakes were positive five times or more even though they appeared healthy. Two samples from feeder rodents were also *Salmonella*-positive, indicating that food is one source of contamination (*72*). Numerous methods have been tried to eliminate salmonellae from reptiles, including antibiotics, probiotics, and a vaccine used for chickens, but none have been very effective either because they failed to rid the animals of salmonellae or because the animals were easily re-infected once treatment stopped (*73*).

Baby poultry have been associated with numerous outbreaks and cases in the past two decades. CDC reports that there have been 45 outbreaks causing at least 1,563 illnesses and 5 deaths in that time period. An in-depth investigation of a prolonged outbreak of S. Montevideo that caused 316 cases (nearly half in

Table 2. Most common *Salmonella* serotypes reported in meat and meat-producing animals in Europe in 2011 (*55*) and the U.S., 2007–2011 (from FSIS PR/HACCP verification samples) (*150*: Salmonella serotypes).

	Cattle	Ground beef	Chickens	Ground chicken	Swine	Turkeys	Ground turkey
U.S.	Anatum Montevideo Dublin Infantis	Montevideo Dublin Cerro Newport Anatum	Kentucky Enteritidis Heidelberg Typhimurium	Kentucky Enteritidis Heidelberg I 4,5,12:i:- Typhimurium	Derby Infantis Johannesburg Copenhagen	Hadar Agona Schwarzengrund Saintpaul	Hadar Saintpaul Heidelberg III 18:z4,z23:-
Europe	Typhimurium Dublin Brandenburg		Infantis Enteritidis Typhimurium Mbandaka		Typhimurium Derby I 4,5,12:i:-	Enteritidis Kentucky Typhimurium Newport	

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children 5 years old or younger) in 43 states from 2004 to 2011 illustrated several factors related to human infection from these animals. Chicks were traced to a hatchery in western U.S. that maintained a closed breeding facility. Several recommendations to the plant, including increased surveillance and sampling, improvements in biosecurity and rodent control, and vaccination, were implemented and led to a decline in cases. Many chicks were sold as pets, and a survey of agricultural feed stores found that many chicks were artificially colored. A majority (59%) of stores said they warned customers about salmonella but 35% said they did not disinfect the chick housing area until the end of the season. Improved practices all along the line from breeders to retail establishments to persons purchasing and handling young poultry are needed to control these outbreaks (*63*).

Other pet birds and small mammals may harbor salmonellae, but dogs and cats are rarely a source of infection for humans.

Wild Animals

Salmonellae are present in a variety of wild animals, including birds, reptiles, rodents, and other mammals, and these animals may transport bacteria around and between farms and into poorly maintained food storage or processing plants and human environments. A report on the 2012 peanut butter outbreak described conditions at the peanut processing plant that allowed potential contamination by birds, rodents, and insects (*151*: Peanut butter outbreaks).

Wild mammals and birds are also hunted and farmed and their meat may be contaminated with salmonellae. Recent reviews indicate that contamination of wild game with *Salmonella* is not common. In Europe, salmonellae were detected most often in lymph nodes and meat from wild boars and less often in meat from ruminants and rabbits. However, available data are inadequate to accurately assess the significance of this contamination (*82;117*). In 2011, there was an outbreak of S. Enteritidis in France associated with consumption of wild boar (*110*).

Insect Transport Hosts

Flies, beetles, mites, and cockroaches are known to acquire pathogenic bacteria and may transport them from animal to animal or from animals to human foods and environments. Available data on insects and mites as transport hosts were recently reviewed in two articles (*16;140*). One insect, the lesser mealworm, is known to survive in poultry litter between rotations of flocks. Experiments demonstrated that when larval mealworms were exposed to *Salmonella*, they excreted the bacteria in frass (feces) for an average of 8 days. When the larvae went through metamorphosis, 19% retained their salmonellae. This may explain the persistence of salmonellae in some poultry operations (*46*).

Serotypes

S. Typhi is the most virulent serovar and still causes large, often waterborne, outbreaks in developing countries, including one in Zimbabwe in 2012 affecting over 4,000 people (*45*). Such large outbreaks do not occur in more developed countries with chlorinated drinking water, adequate sewage treatment facilities, and pasteurized milk. Nevertheless, 285–467 cases of typhoid fever were reported annually in the U.S. during the past 5 years (*39*). Most recent cases are imported by travelers returning from abroad but some have been traced to imported foods (*97*) or to food handlers who may have recently immigrated (*100*). Some large waterborne outbreaks of S. Typhi are listed in the appendix, but only infections transmitted by food or food handlers will be discussed further in this review.

Relatively few of the more than 2,500 non-typhoidal *Salmonella* serotypes are important causes of foodborne disease. Serotypes associated with all the outbreaks described in the literature during the past five years are listed in **Table 3** (*p. 21*) along with their associated vehicles, if known. **Table 4** (*p. 23*)presents similar information for just the outbreaks reported from Canada and the U.S. Some serotypes have been found in or on a variety of foods whereas others appear to be more restricted in their habitat. For example, some serotypes are known to be more tolerant of dry conditions and are the more likely ones to be identified in foods with a low water activity. Although 4 serotypes were associated with egg-related outbreaks in the U.S. in the past 5 years, S. Enteritidis was responsible for over 90% of egg-associated cases during that time. One explanation is that S. Enteritidis survives significantly better in egg white than do other serotypes (*49*).

According to data from FoodNet, during 2011 S. Typhimurium and S. Enteritidis accounted for nearly 31% of *Salmonella* isolates while S. Newport and S. Javiana accounted for another 22% of the serotypes identified. These included both outbreak and non-outbreak serotypes (*30*). S. Enteritidis has caused an increasing proportion of salmonellosis cases in the past decade according to FoodNet data (*42*). According to data gathered on foodborne outbreaks for this review, S. Heidelberg and S. Montevideo are also important causes of foodborne illness. Some *Salmonella* serotypes detected most frequently in human infections are

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also among the most common isolates from cattle, swine, poultry, and meat (Table 2).

Data on serotypes associated with outbreaks in the past five years are depicted in two sets of pie charts: **Figure 3** (*p. 16*) includes all outbreaks (except for the large waterborne outbreaks of S. Typhi); **Figure 4** (*p. 16*) includes data only from U.S. and Canadian outbreaks. S. Typhimurium and S. Enteritidis are the most commonly identified serotypes in the U.S. and many other countries. One exception is Australia, where S. Enteritidis is rare and can usually be traced to travel abroad. The prominence of S. Typhimurium in the international set of outbreaks reflects the large number of S. Typhimurium and lack of S. Enteritidis outbreaks reported in Australia. S. Sofia, a serovar with low virulence for humans, is the major *Salmonella* serotype isolated from Australian chickens. S. Sofia belongs to *Salmonella* subspecies 2 and is occasionally detected in wild birds and reptiles in Australia and Europe, but it is not prevalent in chickens in other countries (*52*).

S. Enteritidis is the most common cause of salmonellosis in Europe, accounting for 44.4% of human isolates serotyped in 2011. S. Typhimurium was identified in 24.9% of 2011 human isolates, with monophasic I 4,[5],12:i:-, Infantis, and Newport rounding out the top five serotypes (*55*). Data from 2008 indicate that S. Enteritidis accounted for 58% of human isolates. The number of cases of salmonellosis in Europe has been decreasing for a number of years, and this is partly a result of decreasing numbers of infections with S. Enteritidis (*111*). There has been a significant increase in multidrug-resistant I 4,[5],12:i:- isolates in Europe in the past decade, largely from pigs and pork. This serovar has also spread to many other countries (*78;84;132*).

S. Enteritidis is also the most common human isolate in Japan. For the past five years the next most common serotypes were Infantis, Thompson, Typhimurium, and Saintpaul (*152*: Japan Salmonella). Although there has been a decline in salmonellosis cases since 2000, there is still year-to-year variation in case numbers rather than constantly decreasing numbers.

Antibiotic Resistance and Human Illness

Salmonellae and other bacteria have been developing or acquiring resistance to antimicrobials since shortly after their introduction. Multidrug resistance is usually associated with large plasmids. Misuse and overuse of antibiotics in treating humans and animals has provided selective pressure, leading to increasing numbers of resistant bacteria. Recently, few new antibiotics have become commercially available, thereby increasing concerns about resistance to important drugs.

Antibiotics are not usually needed for treatment of the gastrointestinal symptoms caused by salmonellae but they are critical for treatment of invasive disease occasionally caused by these bacteria in the immuno-compromised and the very young and very old. (This is a significant concern in countries with a high incidence of HIV infection.) Fluoroquinolines (e.g., ciprofloxacin) and third-generation cephalosporins (e.g., ceftriaxone) are the most important drugs for treating severe salmonellosis in the U.S. Resistance to naladixic acid, a quinoline, is correlated with increased resistance to ciprofloxacin. In the 1990s, S. Typhimurium DT104, resistant to ampicillin, chloram-phenicol, streptomycin, sulfonamides, and tetracycline (referred to as ACSSuT), emerged in Europe and has since spread to many other countries. This pattern of multidrug resistance has been detected in several other important serovars, including Newport, Heidelberg, Infantis, Paratyphi B, and I 4,[5],12:i:-. Some S. Typhimurium, Infantis, and Newport strains are also resistant to amoxicillin-clavulanic acid and ceftriaxone (ACSSuTAuCx) (*138*). **Table 5** shows the percentage of human salmonella isolates tested by NARMS in 2010 that exhibited resistance to important antibiotics (*31*). **Table 6** presents antibiotic resistance data on salmonella isolates from food animals.

Data from Europe in 2010 indicate resistance to third-generation cephalosporins in salmonellae from animals and from chicken meat and pork ranged from 0.2 to 7%. Resistance to ciprofloxacin and naladixic acid was highest in isolates from turkeys, chickens, and chicken meat, detected in 24–28% of isolates. Significant variations in resistance were reported from different countries (*56*).

Some recent review articles on antibiotic resistance in salmonellae from food animals provide more details on emerging patterns and mechanisms of resistance (*86;99*). A comprehensive review discusses the challenges that antibiotic-resistant bacteria present to the food industry. It includes information on trends in antibiotic resistance in recent decades and their economic and health consequences along with routes for emergence and dissemination of resistance and approaches to prevent and control the development and spread of resistance in the food industry (*25*).

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Table 5. Percentage of 2010 human isolates of *Salmonella* serotypes from the U.S. with important antibiotic resistance (*31*).

Serotype	Naladixic acid	Ceftriaxone	ACSSuT	ACSSuTAuCx
Enteritidis	5.2%	0	0	0
Heidelberg	0	24.2%	1.6%	0
Newport	0.3%	7.2%	7%	7%
Typhimurium	1.4%	4.9%	18.6%	1.9%

Table 6. Percentage of 2010–2011 *Salmonella* isolates from animals in the U.S. with important drug resistance (*153*: NARMS reports).

Animal source	Naladixic acid	Ceftriaxone	ACSSuT	ACSSuTAuCx
Cattle	1.8%	14.4%	18.6%	16.2%
Chickens	0	6.3%	2.3%	2.0%
Swine	0	2.2%	7.2%	0.9%
Turkeys	0	11.7%	4.0%	1.3%

Routes or Vehicles of Human Infection

Fecal material from infected humans and animals is the ultimate source of most *Salmonella* infections and may contain up to 10^4 to 10^{10} CFU of *Salmonella*/g feces. Shedding usually continues for weeks, months, and even years in some cases, even though the person or animal has no symptoms of illness (*70*). Therefore, even very small amounts of fecal material on a person's hands, an animal's body, or in the environment where an animal lives may contain large numbers of bacterial cells. In addition, manure from infected animals may be added to soil as fertilizer or wash into nearby bodies of water, thereby potentially contaminating crop plants and drinking water. Vehicles of infection reported for *Salmonella* outbreaks in the past five years are listed in **Table 7** (all outbreaks) (*p. 25*) and **Table 8** (U.S. and Canada only) (*p. 26*) along with the responsible serotypes and numbers of cases, and the relative importance of different vehicles is depicted in **Figures 5** and **6** (*p. 17*). More details on vehicles of infection are included in the following sections, and outbreaks are listed in the appendix. **Table 9** presents a comparison of outbreaks attributed to different vehicles in this review update, in the previous FRI white paper (*149*), and in a recently published attribution study of food vehicles (*14*).

Table 9. Comparison of attribution of outbreaks to different vehicles expressed as a percentage of all outbreaks (first 3 lines) or as a percentage of only food-associated outbreaks (last 3 lines).

Study	Meat	Eggs	Dairy	Produce	Seafood	Person-to-Person	Animals
2013 FRI review update (all)	29	27	3	13	3	1	5
2009 FRI white paper (all)	24	20	7	17	3	4	8
2013 FRI review update (US–CAN)	33	8	3	19	3	1	8
2013 FRI review update (US–CAN)	37	9	3	21	3		
2012 CDC paper (CDC data) (*14*)*	37	12	6	18	5		
2012 CDC paper (experts) (*14*)	55	22	7	12	2		

*This paper used CDC outbreak data from 1999–2008.

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Direct Contact

Person-to-person spread of salmonellae is the primary route of infection in outbreaks in daycares, hospitals, and other institutions, particularly where there have been lapses in hygiene. In other outbreaks, some individuals who consumed contaminated food or water and developed diarrhea, passed the infection directly to others in their families. However, according to a CDC study of data on 2009–2010 outbreaks of acute gastroenteritis in the U.S. transmitted by person-to-person contact, only 16 of the 1,419 outbreaks with known etiology were caused by salmonellae. Norovirus was the cause of 89% of these outbreaks (*142*).

Pets and farm and wild animals shedding salmonellae may pass infections to humans who handle them or materials contaminated with their feces. Analyses of FoodNet data led epidemiologists to estimate that 11% of *Salmonella* infections in the U.S. are attributable to contact with animals and their environment. This includes contact with pets, livestock, or wild animals or their feces or environment. Contact with farm animals may include both occupational exposure and contact at fairs, petting zoos and other places (*47;75*).

During the past five years, there have been a total of 25 reported outbreaks, affecting 2,244 people, that were traced to chicks, hedgehogs, aquatic frogs, pet turtles, bearded dragons, and a bandicoot. There were no reported outbreaks specifically associated with petting zoos or farm visits in the past 5 years, yet the percentage of cases associated with animal contact tripled. Several of the turtle outbreaks and the frog outbreak spanned several years. As has been true in the past, most of the cases were young children. Most of the implicated turtles were small (<4 inches in length, the legal limit for sale) and some were actually being sold in established pet shops (*38;105*). Bearded dragons have become popular pets recently and in a Minnesota outbreak they somehow contaminated the gravy prepared by an asymptomatic owner for a pot-luck dinner *(101*). Some severe *Salmonella* infections in infants were traced to reptiles living in the home, even though the infants were not directly exposed to the animals; caregivers must have transferred the salmonellae to the babies (*108;112*).

According to CDC (*154*: CDC Salmonella), there have been 22 outbreaks linked to live young poultry in the U.S. in the past five years. (Not all of these outbreaks are included in tables because details have not been published.) An unusual outbreak occurred among children in a town in Australia. After an extensive investigation, it was determined that exposure to playground sand in public parks and childcare centers was associated with infection. The outbreak strain of Paratyphi B was isolated from sandboxes and from a local wild animal, the long-nosed bandicoot (*130*).

Humans have also been infected with salmonellae by handling pet food. A prolonged outbreak involving hundreds of cases caused by monophasic S. Typhimurium (I 4,[5],12:i:-) in England was eventually traced to a Texas facility that produced rodents to feed snakes and other carnivorous pets. The same plant was implicated in an earlier U.S. outbreak traced to feeder rodents (mentioned in the previous FRI white paper, *149*) and to 46 cases in the U.S. in 2011–2012. This facility has been closed (*77;94*).

Some other human illness has been associated with dry dog food or dog treats. Only one outbreak of human illness was described in the past 5 years but there has been an ongoing series of recalls of pet food by FDA for *Salmonella* contamination.

Contaminated Food

Meat. For outbreak data in this review (2007–2013), meat accounted for 29% of all outbreaks and 33% of outbreaks in the U.S. and Canada with a known vehicle (*see* Figures 5 and 6). Although meat was linked with 33% of US–Canada outbreaks, it caused only 19% of cases. A higher percentage of outbreaks was linked to meat in the past five years compared to data in the previous white paper (*see* Table 9). A recently published paper on attribution of foodborne illness using CDC outbreak data (1999–2008) calculated that meat accounted for a similar percentage of foodborne salmonellosis outbreaks (Table 9). Expert solicitation judged that meat caused 55.2% of outbreaks (*14*). The importance of different categories of meat in reported outbreaks and cases of salmonellosis is illustrated in **Figures 7** and **8** (*p. 18*). Poultry was responsible for 44% of the meat outbreaks. This was about 11% greater than the percentage reported in the 2009 FRI white paper (*149*). The percentages for beef- and pork-associated outbreaks are a little higher than previously reported but the differences may not be significant.

However, Americans do not consume equal amounts of beef, pork, and poultry. According to USDA data from 2011, about 44% of the meat used in the U.S. is poultry, 32% is beef, and 22% is pork (*135*). For just these categories of meat, percentages of foodborne outbreaks in the U.S. associated with poultry, beef, and pork, and were 54%, 20%, and 26%, respectively. Therefore, *Salmonella* in poultry and pork does cause more outbreaks than might be expected from its level of consumption.

A newly recognized issue in *Salmonella* contamination of ground meat is the detection of

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salmonellae in bovine lymph nodes. While some lymphatic tissue is discarded during processing, other lymph nodes are incorporated into ground beef. One study detected *Salmonella* in 18% of lymph nodes from 100 cull dairy cows (*91*). A survey of *Salmonella* in lymphatic tissue of cattle from 7 feed yards found very low contamination rates in cattle from some yards (0–4%) and a very high rate in one yard (88%). Repeated trips were made to feedyards to collect samples but the differences in contamination rates between the yards persisted. This study did not determine what environmental factors might account for such a large difference in rates of contamination (*76*).

Processed meats such as ham, salami, and sausage accounted for about 8% (9% U.S. and Canada) of the meat outbreaks. In addition, a small number of cases and outbreaks were traced to other meats, including lamb and wild game. Some other outbreaks were attributed to "meat", which may indicate a mixture of meats or cross-contamination in a butcher shop or kitchen where it was impossible to identify the original source of the salmonellae.

Eggs. Eggs are an important vehicle for salmonellosis, particularly for S. Enteritidis. This serotype can pass through egg shells after eggs are laid and, more significantly, can also infect the reproductive systems of hens and be deposited in the egg contents prior to egg shell formation. Experimental infection of hens with an oral dose of 10^4 cfu S. Enteritidis resulted in contamination of 0.7% of eggs whereas a dose of 10^8 cfu contaminated 10.8% of eggs (*66*). S. Enteritidis was present in both yolks and albumen. S. Typhimurium and other serovars generally contaminate the outside of eggs although it has been reported that S. Typhimurium can occasionally infect the hen's reproductive tract (*103*).

For outbreak data in this review (2007–2013), eggs accounted for 27% of all outbreaks and 8% of outbreaks in the U.S. and Canada with a known vehicle (*see* Figures 5 and 6). While eggs caused a relatively small percentage of outbreaks in the U.S., they were implicated in 21% of salmonellosis cases. A higher percentage of outbreaks was linked to eggs in the past five years compared to data in the previous FRI white paper (*see* Table 9). A large outbreak of S. Enteritidis, affecting over 1,900 people was traced to shell eggs from Iowa in 2010 (*28*). Egg-associated outbreaks in Australia are predominantly caused by S. Typhimurium.

Seafood. Seafood is not generally considered an important vehicle for salmonellosis. However, shellfish, which are filter feeders that can concentrate bacteria, may become contaminated in inshore areas. A large outbreak in 2012 was caused by *Salmonella* contamination of "scrape" tuna, back meat scraped from bones of the fish. Due to a tuna shortage, this product was sourced from a company in Asia without adequate pathogen control programs and the tuna scrape was frozen and then used in sushi (*34*). For outbreak data in this review (2007–2013), seafood accounted for 3% of all outbreaks and 3% of outbreaks in the U.S. and Canada with a known vehicle (*see* Figures 5 and 6).

Fruits and vegetables. Fresh produce has become an important vehicle for foodborne infections, being associated with 19% of salmonellosis outbreaks in the U.S. and Canada in the past 5 years (*see* Figure 6). A recently published paper (*14*) on attribution of foodborne illness estimated that produce caused a lower percentage of outbreaks (*see* Table 9).

Figure 9 (all outbreaks) and **Figure 10** (U.S. and Canada only) (*p. 19*) illustrate the significance of different categories of produce (fruits, greens, sprouts, and tomatoes/peppers) in causing reported outbreaks and cases of salmonellosis. In contrast to the previous FRI white paper (*149*), during the past five years tomatoes/peppers caused a relatively small number of outbreaks, with greens, fruit, and sprouts causing about 85% of outbreaks.

There are many potential routes for contamination with salmonellae: from the farm field through harvest, cleaning, storage, and retail sale. Salmonellae can attach to leaves and fruits and in some cases can penetrate into plant parts so that they cannot be washed off (*50;83;145*). Two recent reviews of human bacterial pathogens and crop plants discussed factors affecting the ability of these bacteria (including *Salmonella*) to colonize and survive on plants (*13;21*). Experiments have demonstrated that *Salmonella* can be taken up from the soil by roots. *Salmonella* Newport appeared to more capable of colonizing tomatoes than S. Typhimurium (*145*). Numerous other papers have been published recently on interactions between bacterial pathogens and plants. Preventing contamination of plants that will be consumed without cooking is important because it is difficult or impossible to remove bacteria once they attach and become internalized.

Sprouts continue to cause hundreds of cases of salmonellosis. Seeds may be contaminated during growth and harvest or from contaminated equipment or water at the germination facility. Interventions using sanitizers and heat have been tried (sometimes with little success) to reduce contamination on seeds. During germination, bacteria can be internalized inside the sprouts. A recent review considered various factors contributing to contamination and possible interventions (*144*).

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Other foods. Unpasteurized dairy products, bakery goods, peanut butter, and some combination foods were responsible for other outbreaks in the past 5 years. Of particular interest are three outbreaks involving dry products. In 2008–2009, S. Typhimurium caused 75 cases of illness in New Zealand linked to a specific brand of flour. The outbreak strain was also isolated from poultry feed containing broll (husk of the wheat kernel that is removed during milling). Trace back revealed that one flour mill produced both the broll and the implicated flour. It was not possible to further trace the source of the contaminated wheat (*67*).

Two other outbreaks were linked to spices. One outbreak at first appeared to be another meat-associated outbreak because epidemiological studies implicated salami. However, trace back to the plant producing the salami revealed that the outbreak strain of S. Montevideo was present in sealed containers of black and red pepper that were used to flavor the salami. In this case, a ready-to-eat product was contaminated post-processing with a contaminated raw spice (*90*). An uncommon serotype, S. Rissen, more often observed in southeast Asia, was isolated in an outbreak in 2009 in California, Oregon, and Nevada. Many of the cases reported eating at Asian restaurants or had Asian surnames. S. Rissen was eventually isolated from ground white pepper from a company supplying Asian restaurants (*81*). Two recent reviews discuss *Salmonella* outbreaks related to spices and herbs (*146*) and low water activity foods as vehicles of foodborne illness (*15*). An FDA survey of imported spices found a low prevalence of contamination with salmonellae. Highest prevalence (0.11–0.15) was detected in coriander seeds, dried oregano/basil, and sesame seeds. A wide variety of serotypes were detected and some antibiotic-resistant strains were identified. There was also some variation in contamination levels according to the export country (*136*).

Peanuts contaminated with *Salmonella* have caused several outbreaks traced to peanut butter and resulted in massive recalls of peanut-containing products. Contributing factors to outbreaks include poor sanitation and plant design and lack of adherence to good manufacturing practices. A recent survey of food safety issues related to peanuts notes that they also contain allergenic proteins of concern to many and may be contaminated with aflatoxigenic fungi (*44*).

Food handlers. Although food handlers may appear asymptomatic, they may be still shedding bacteria from a previous illness, and lapses in hygiene may result in contamination of food. Only a few recent outbreaks were reported as associated with food handlers; there were many other outbreaks where multiple foods were implicated, suggesting that one or more food handlers were cross-contaminating several food items. There were two outbreaks of S. Typhi in France that occurred at festivals or ethnic restaurants, which suggested to epidemiologists that recent immigrants working at these establishments were responsible for the contamination. A large outbreak in Bosnia was associated with chicken and food handlers.

Contaminated Water

Water containing fecal material is known to be a major vehicle for typhoid fever in developing countries; this may result from contamination by asymptomatic people who harbor S. Typhi for long periods of time (*70*). In developed countries, waterborne outbreaks of salmonellosis are uncommon but still occur occasionally when drinking water sources are contaminated with animal or human feces. Contaminated irrigation and processing water have been implicated in several disease outbreaks traced to fresh produce. A search for possible *Salmonella* reservoirs at tomato fields in the U.S. associated with foodborne outbreaks identified irrigation water as a habitat harboring *Salmonella*, including four serotypes associated with outbreaks (*106*). A recent review discussed data on the prevalence of *Salmonella* in surface, drinking, and ground water and their possible association with human illness. *Salmonella* is commonly detected in aquatic habitats, and contamination increases from runoff after rainfall (*95*).

RESPONSES TO *SALMONELLA* OUTBREAKS

Surveillance

Human Illness

Reports of foodborne illness and cases of other notifiable diseases from U.S. clinical laboratories are reported by all state health departments to CDC under the National Notifiable Diseases Surveillance System (NNDSS). CDC then publishes weekly and annual reports of notifiable diseases and reports of foodborne illness. However, there are dramatic differences among states in the priority and funding given to investigation of foodborne illness and notifiable illnesses and their aggressiveness in tracking down causes of outbreaks and sporadic cases. For example, rates of reported *Salmonella* outbreaks/10 million population vary by 30-fold among states (*88*).

It is likely that only a fraction of cases that occur are reported to CDC by passive surveillance systems. FoodNet (Foodborne Diseases Active Surveillance

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Network) is a collaborative active surveillance project in the U.S. to track foodborne illness and now collects information for about 15% of the U.S. population. Data from 2011 FoodNet sites indicate that the incidence of salmonellosis has not changed significantly in recent years (*see* Figure 1) (*30*).

PulseNet is a national network of laboratories that perform standardized molecular subtyping of food-borne pathogens and submit them to a central database (*155*: CDC PulseNet). This allows comparison of similar strains from different localities that may be part of a multistate outbreak of foodborne illness. Similar PulseNet systems have been set up in Canada, Europe, and other parts of the world. PulseNet International coordinates these international sites with the goal of identifying international outbreaks of food- and waterborne disease as well as acts of bioterrorism (*156*: PulseNet International). This group also aids developing countries in setting up laboratories and national PulseNet systems. PulseNet Latin America and Caribbean has been working with PulseNet International to determine the diversity of *Salmonella* strains in the region. This will aid not only investigations of local foodborne outbreaks but also of international outbreaks because of the widespread global trade of foods (*24*).

Canada has a surveillance system for infectious enteric diseases, C-Enternet, that is similar to CDC's FoodNet system (*157*: C-EnterNet). An annual report is published that includes information on pathogens in human cases at sentinel sites as well as surveys of pathogens in farm animals and food.

Australia has an active surveillance program for foodborne disease, OzFoodNet, which is similar to FoodNet in the U.S. (*158*: OzFoodNet). Annual and quarterly reports are published with discussions of trends and significant outbreaks in Communicable Diseases Intelligence (*159*: CDI) (*113*). Salmonellosis is also a notifiable disease in Australia and this surveillance data is published on the web (*160*: Notifiable Diseases).

The European Centre for Disease Control and Prevention (ECDC) (*161*: ECDC) gathers surveillance data from countries in the European Union and some non-EU countries and publishes surveillance and epidemiological reports as well as alerts on significant outbreaks. The European Food Safety Authority (EFSA) conducts risk assessments and evaluations of the safety of various substances in foods and publishes its reports along with epidemiological reports from ECDC in *EFSA Journal* on-line (*162*: EFSA Journal).

Animals

FSIS tabulates annual results of its *Salmonella* testing program to track progress in controlling this pathogen in cattle, hogs, young chickens, and turkeys. In 2012, results from PR/HACCP Verification Testing Program indicated salmonellae were present in 4.3% of broilers, 1.3% of hogs, 0% of cows/bulls, 0.5% of steers/heifers, and 2.2% of turkeys tested. (*163*: FSIS Salmonella testing). FSIS has also published an analysis of *Salmonella* serotype incidence on FSIS regulated products as compared to serotypes identified in salmonellosis outbreaks listed by CDC to support its conclusion that reducing all serotypes on chicken and turkey would have a significant impact on reducing human salmonellosis (*164*: FSIS serotype incidence).

European Union publishes results of tests for salmonellae in poultry from member countries annually. From the latest report, salmonellae were detected in 1.9% of chicken breeding flocks, 4.2% of laying hen flocks, 3.2% of broiler flocks, and 10.1% of fattening turkey flocks. Prevalence of *Salmonella* has declined significantly in poultry flocks since 2008 when the mandatory *Salmonella* control program was implemented (*55*).

Several recent studies have surveyed prevalence of *Salmonella* in various food animals:

- A recent review on pathogens of interest to the pork industry included several tables summarizing prevalence of *Salmonella* in pigs in many countries: on farms and at slaughter (*11*)
- 39.7% of 896 pig carcasses in Spanish slaughter-houses tested positive for *Salmonella* (*9*)
- 32.6% of culled dairy cows in Texas were positive for *Salmonella*; in herds vaccinated with a commercial *Salmonella* vaccine, 8% of cows tested positive for salmonellae; in unvaccinated herds, prevalence was 36.8% (*98*)
- Mean prevalence of *Salmonella* in farmed ducks from several countries was 19.9% in ducks and 17.5% in/on duck eggs (*2*)
- A high prevalence (43%) of *Salmonella* was detected in tonsils of sheep at slaughter in Switzerland even though their feces tested negative; prevalence in tonsils of goats was only 2% (*19*)

Food

An integrated surveillance system for *Salmonella* in the food chain was begun in British Columbia in 2006. An evaluation of this system identified several critical elements of the program (dedicated people, sharing and integration of data, multidisciplinary analysis, and

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collaborative responses) and ongoing challenges to sustain the system (*64*).

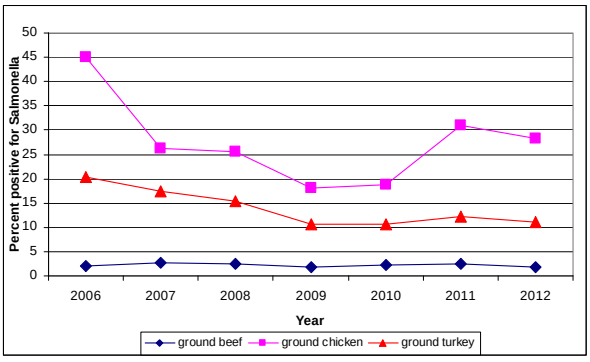
A web-based system, Pathogen-Annotated Tracking Resource Network (PATRN), has been developed to address data collection, analysis, and communication needs for investigation of foodborne illness by the global community. Currently, it has data on 6 pathogens, including *Salmonella*, and genome data can be used to evaluate the relatedness of different strains. A variety of computational tools aid in managing, analyzing, and visualizing data (*69*).

FSIS publishes annual results of its *Salmonella* testing program for this pathogen in beef and poultry. Baseline data, collected in 1995 for ground chicken and turkey and in 1993–1994 for ground beef, are used to gauge progress in controlling salmonellae in processing plants. Results from the past five years are presented in **Table 10**. As depicted in **Figure 11**, *Salmonella*-positive samples have remained low for ground beef and decreased significantly for ground chicken in 2009–2010 but have increased again in the two most recent years.

Table 10. Percent positive *Salmonella* tests in the PR/HACCP verification testing program.

Time period	Ground beef	Ground chicken	Ground turkey
2012 (preliminary)	1.86%	28.2%	11.10%
2011	2.4%	30.9%	12.3%
2010	2.2%	18.8%	10.2%
2009	1.9%	18.2%	10.7%
2008	2.4%	25.5%	15.4%
2007	2.7%	26.3%	17.4%
2006	2.0%	45.0%	20.3%
1998–2005 (A samples)	1.6%	25.5%	19.9%
Baseline (1993–1995)	7.5%	44.6%	49.9%

Figure 11. Positive samples in the USDA PR/HACCP verification testing program.



Pork and other meat. A recent review on pathogens of interest to the pork industry included a table summarizing prevalence of *Salmonella* in pork products at retail (*11*). *Salmonella* was detected in 2.2% of 1777 samples of meat from sheep in Australia (*119*).

Eggs. Although raw and undercooked eggs are commonly associated with foodborne salmonellosis, the low numbers of *Salmonella* cells in contaminated eggs makes them difficult to detect. A PCR method was found to be much more sensitive in detecting salmonellae in eggs than bacteriological culture methods (*74*). A review of *Salmonella* serovars detected in eggs during surveillance studies emphasized the importance of S. Enteritidis and some other serotypes. S. Typhimurium is seldom detected in eggs (*103*) but is commonly associated with egg-linked illness in Australia. A recent survey in Japan using culture methods to detect S. Enteritidis in eggs found a very low prevalence (0.003%) (*57*).

Peanuts. A survey of 944 raw shelled peanut samples from the 2008–2010 harvests found that only 2.33% were contaminated with *Salmonella*. Ten *Salmonella* serovars were detected, including S. Tennessee that was associated with a peanut butter outbreak and several other serotypes that have caused human illness (*23*).

Spices. Prevalence of *Salmonella* in imported dried spices was investigated by FDA in 2007–2009. Overall prevalence was low (<0.2%) but there was variation according the country of origin and the state of the spice (whole or cracked/ground) (*136*).

Pet food. Surveillance studies indicated the presence of salmonellae in about 25% of pig ear treats for dogs (*1*) and in 7% of raw meat pet food (*104*). Surveillance data from FDA on contaminants in feed demonstrated an average contamination rate of 12.5% (2002–2008). Contamination rates were highest in feed ingredients. There was a significant reduction in contamination between 2002 (18.2%) and 2008 (8%) (*96*). Nevertheless, there is an ongoing series of recalls of pet food by FDA for *Salmonella* contamination. In the first 3 months of 2013 this has already included dry pet food, frozen pet food, and pet treats sold under 7 brand names. FDA is planning to collect and analyze more samples of pet food and treats for *Salmonella* contamination (*165*: FDA pet food).

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Interventions

Dry and Low-Water-Activity Foods

Low-water foods and ingredients, including peanut butter, flour, and spices, have been implicated in recent outbreaks. Pathogens may survive for long periods of time in these foods (*17*). Approaches to minimize safety risks were discussed in a recent review (*15*). Although wet cleaning is necessary to remove allergens and is usually necessary to verify pathogen destruction, it is difficult to use in plants manufacturing dry ingredients because of possible contamination. These issues were discussed with reference to several case studies, and hygienic indicators were recommended to solve problems associated with cleaning these environments (*92*).

Eggs and Poultry

A recent publication contained an in-depth discussion of preharvest and postharvest methods to control salmonellae in poultry and eggs. Postharvest methods to prevent growth of salmonellae in eggs include cool storage temperatures and chemical and physical methods for decontaminating the shell surface. Preharvest strategies included competitive exclusion, vaccination, feed management and testing, sanitation and biosecurity of poultry-houses, flock management protocols, and selection of genetically resistant animals (*65*). Another review specifically addressed the literature related to the effectiveness of vaccination programs and biosecurity measures (*133*). Other reviews also discussed issues related to egg safety (*85;118*).

Risk factors for *Salmonella* on fattening turkey farms included the presence of mice around turkey houses, poor water quality for birds, and some factors related to sanitation (*60*). A scientific opinion from the EFSA panel on biological hazards discussed turkey raising in Europe, epidemiology of *Salmonella* in turkeys, and the public health impact of reducing important serovars in turkeys (*54*).

Pigs and Pork

Five on-farm interventions for *Salmonella* reduction in swine were evaluated for efficacy using data from controlled trials. Ranking of the procedures was, in order of decreasing effectiveness: feeding meal rather than a liquid diet > adding acid to diets, feeder pen disinfection, vaccination > in-feed tetracyclines. Supporting data were presented and discussed (*143*). More attention to biosecurity on farm and better sanitation during lairage were recommended in two studies that examined stages at which contamination of pigs occurred (*18;102*). A modeling approach was developed to aid in determining appropriate steps for controlling *Salmonella* on farms. Infection characteristics and factors such as biosecurity and sanitation could be entered to determine some useful control strategies (*129*).

Lessons learned from the Danish Salmonella Surveillance and Control program for finisher pigs and pork were discussed in a recent report. An analysis on control actions applied along the food chain found that it would be most cost effective now to deal with *Salmonella* at the abattoirs rather than in herds. Identification of high-risk herds at the abattoir (with a penalty system for farmers with relatively highly contaminated animals) and increased attention to slaughter hygiene with hot water decontamination of high-risk pigs should further reduce prevalence of *Salmonella* in pork to <1% (*4*).

Produce and Sprouts

Following several large salmonellosis outbreaks associated with cantaloupe, a commercial-scale surface pasteurization process was developed to improve safety of these fruit. Hot water (92°C) immersion for 60 sec reduced inoculated populations of S. Poona by >5 logs. Since the interior temperature of the cantaloupe was about 30–32°C (previous storage temperature) at this time, this brief exposure to hot water did not adversely affect firmness of the fruit. *Salmonella* levels remained low during refrigerated storage for at least 9 days (*6*).

Sprouts continue to be an important vehicle for infection with both *Salmonella* and *E. coli*. Two recent papers reviewed the effectiveness of several seed decontamination methods. Several treatments have been shown to reduce pathogens on seeds but treatment intensity must be balanced against the need to maintain sprouting ability of the seeds. Therefore, a combined approach using some heat followed by a chemical sanitizer may be an effective approach. Other procedures such as high pressure and irradiation also destroy pathogens (*51;144*).

Regulations and Recommendations

FDA proposed, on Jan. 4, 2013, two new food safety rules to implement the Food Safety Modernization Act and help prevent foodborne illness: "*Current Good Manufacturing Practice and Hazard Analysis and Risk-Based Preventive Controls for Human Food*" and "*Standards for the Growing, Harvesting, Packing and Holding of Produce for Human Consumption*" (*166*: FDA_FSMA). (The comments period for these rules extends to September 16, 2013.) These new rules are complex and will affect several areas of food

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production and processing as FDA aims to establish procedures that more effectively prevent and control pathogen contamination and growth in foods.

Eggs and Poultry

FDA posted its final egg safety rule, "*Prevention of Salmonella Enteritidis in Shell Eggs during Production, Storage, and Transportation*," in the Federal Register in July 2009 (*167*: FDA shell eggs). In March 2011, FSIS posted its new performance standards for *Salmonella* in broiler and turkey slaughter establishments: 5 positive samples of 51 will be acceptable for broilers and 4 positive samples for 56 turkey samples will be accepted (*168*: FSIS performance standards). In August 2012, FDA published further guidance for industry on the prevention of S. Enteritidis in shell eggs (*169*: FDA shell eggs Q&A).

A four-stage national program to control *Salmonella* in poultry and eggs was implemented in the UK over four years. In 2007, the target was reducing *Salmonella* in breeding chickens; in 2008, the target was laying hens; in 2009, broilers were targeted; and in 2010, turkey flocks were targeted for *Salmonella* reduction. This program along with similar programs in other European countries has resulted in significant reductions in *Salmonella* prevalence in poultry and eggs and in human infections (*111*).

Antibiotic Resistance

In April 2012, FDA, in response to concerns about resistance to important human antibiotics among human pathogens, published three documents in the Federal Register offering guidance to farmers and animal producers, veterinarians, and drug companies on the judicious use of medically important antibiotics in food producing animals (*170*: FDA antibiotics)

- A final guidance for industry, "*The Judicious Use of Medically Important Antimicrobial Drugs in Food-Producing Animals*," that recommends phasing out the agricultural production use of medically important drugs and phasing in veterinary oversight of therapeutic uses of these drugs.
- A draft guidance that will assist drug companies in voluntarily removing production uses of antibiotics from their FDA-approved product labels; adding, where appropriate, scientifically supported disease prevention, control, and treatment uses; and changing the marketing status to include veterinary oversight.
- A draft proposed Veterinary Feed Directive regulation that outlines ways that veterinarians can authorize the use of certain animal drugs in feed, which is important to make the needed veterinary oversight feasible and efficient.

Animal Contact

The National Association of State Public Health Veterinarians, Inc. has published an updated "*Compendium of Measures to Prevent Disease Associated with Animals in Public Settings*" (*53*). These recommendations are aimed at a variety of venues, including fairs, petting zoos, pet stores, camps, and even wildlife photo opportunities. Hand washing is still the most important means of reducing disease risk, and this update includes more information on educating children and other participants about zoonotic diseases and risks associated specifically with amphibians.

It has been illegal since 1975 to sell turtles in the U.S. that have a shell length of <4 inches and this has probably been the most effective means of reducing turtle-associated salmonellosis in young children. Nevertheless, the continuing reports of turtle-associated outbreaks indicate that some are ignoring this law. Because reptiles frequently carry *Salmonella* and are a well known source of infection, one might expect that they would be banned from childcare centers. However, a 2011 survey of state regulations for contact between children and animals in childcare centers found that there was great variation among states. Only 12 states banned reptiles, and only 3 of these also banned amphibians. Nearly half of states banned "potentially dangerous animals" and animals that appeared to be sick. However, only half of states required teachers and children to wash their hands after handling animals (*139*). CDC recommends that turtles and other reptiles not be kept in childcare centers, homes with young children, or homes with immunocompromised individuals (*171*: CDC turtles).

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SUMMARY

Over the past five years since the previous FRI white paper on *Salmonella* and its vehicles of infection (*149*), there has not been much progress overall in reducing salmonellosis in the U.S. Incidence of salmonellosis was estimated at 14.89 cases/100,000 persons in 2007 and, according to the most recent figures, was 16.4/100,000 in 2012. However, salmonellosis incidence in Europe continued to decline from 34.2/100,000 in 2007 to 20.7/100,000 in 2011. This was attributed to programs instituted in 2007 to better control *Salmonella* in breeding flocks, laying hens, broilers, and eggs. National programs have also addressed preharvest controls for swine.

There have been some changes in important serotypes and vehicles of infection. S. Typhimurium has declined as a percentage of serotyped *Salmonella* isolates from FoodNet sites, from 15% in 2007 to 13% in 2012. S. Enteritidis isolates increased from 16% to 18% during this time while S. Newport increased from 10% to 13% of identified *Salmonella* isolates (*172*: CDC FoodNet). In Europe, there has been a significant increase in multidrug-resistant I 4,[5],12:i:- isolates in the past decade, largely from pigs and pork. This serovar caused 3 large outbreaks in France in the past 5 years, with pork and beef determined to be vehicles. This strain has also spread to many other countries. Antibiotic resistance remains a concern as some *Salmonella* isolates from humans and animals are resistant to third-generation cephalosporins and some have reduced sensitivity to fluoroquinolines.

Meat and eggs continue to be important vehicles for salmonellosis, generally responsible for 40–50% of outbreaks and cases. Some of the outbreak vehicles categorized as "combination foods" or "bakery products" may actually have a meat or egg ingredient that was the original source of contamination.

With regard to produce, fruit has become important as a vector, with some large outbreaks attributed to melons. In contrast to the previous FRI white paper, during the past 5 years tomatoes/peppers caused a relatively small number of outbreaks, with greens, fruit, and sprouts responsible for about 85% of outbreaks. There is a great deal of current research investigating survival of salmonellae on different plants and possible methods for decontamination while still maintaining the integrity of the leaf, sprout, or fruit so that it can be eaten fresh.

There were no reported outbreaks specifically associated with petting zoos or farm visits in the past five years, yet the number of cases associated with animal contact tripled. During the past five years, there have been a total of 25 reported outbreaks, affecting 2,244 people that were traced to chicks, hedgehogs, aquatic frogs, pet turtles, bearded dragons, and a bandicoot. It appears that organized events (fairs, petting zoos, etc.) have made progress in preventing *Salmonella* transmission. But individuals purchasing baby poultry and reptiles need more education on hygiene measures necessary to prevent infections, particularly for more vulnerable people. Some breeders and sellers of these animals also need to improve sanitation at their premises to prevent *Salmonella* infection/carriage by their animals.

In analyzing outbreak data for clues to the epidemiology of salmonellosis, it is wise to remember that CDC estimates that about 95% of *Salmonella* infections are sporadic, i.e., not linked to a recognized outbreak. Nevertheless, CDC believes that over 85% of these cases result from foodborne infection. Many sporadic cases may be due to the same foods that cause outbreaks but we may be missing some foods or other vehicles of salmonellosis.

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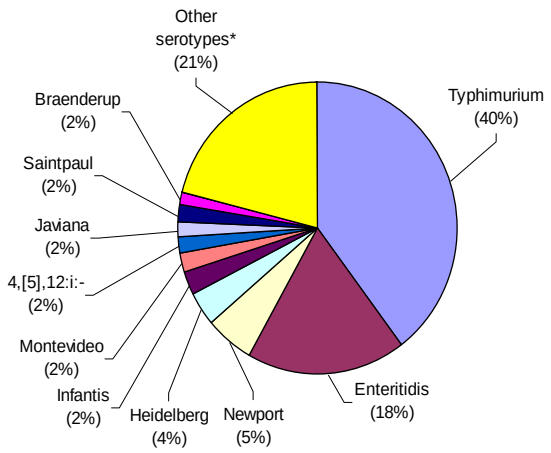
Figure 3. *Salmonella* serotypes reported as causes of outbreaks and cases of human salmonellosis (all outbreaks with identified serotype except for 4 large waterborne outbreaks of S. Typhi).

Outbreaks



Cases

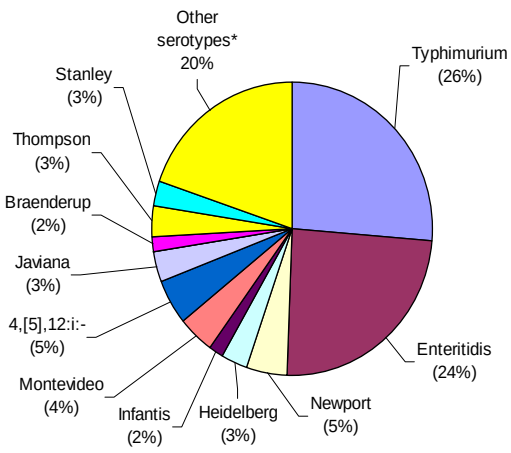
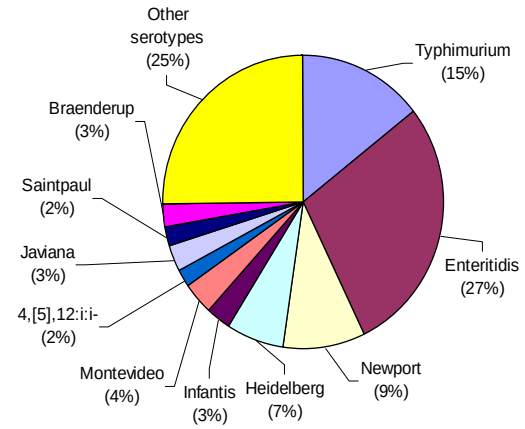


Figure 4. *Salmonella* serotypes reported as causes of outbreaks and cases of human salmonellosis in the US and Canada (all outbreaks with an identified serotype).

Outbreaks



Cases

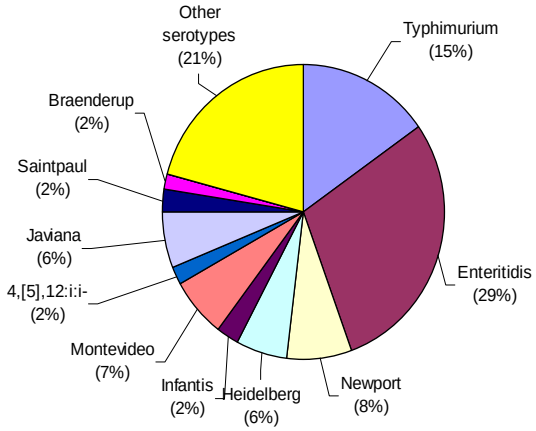


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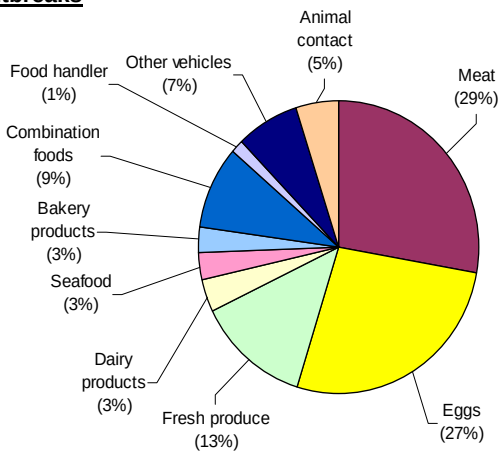
Figure 5. Vehicles for non-typhoidal salmonellosis outbreaks (all outbreaks with known/suspected vehicles except for large waterborne outbreaks of S. Typhi).

Outbreaks



Cases

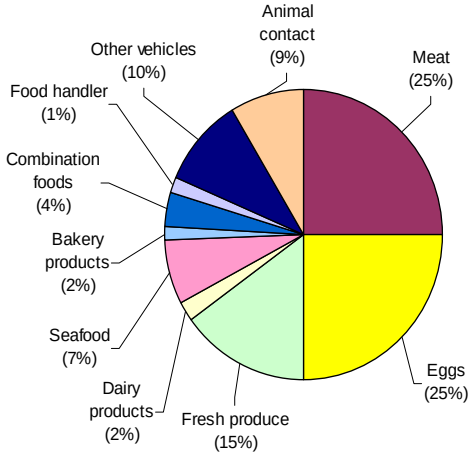
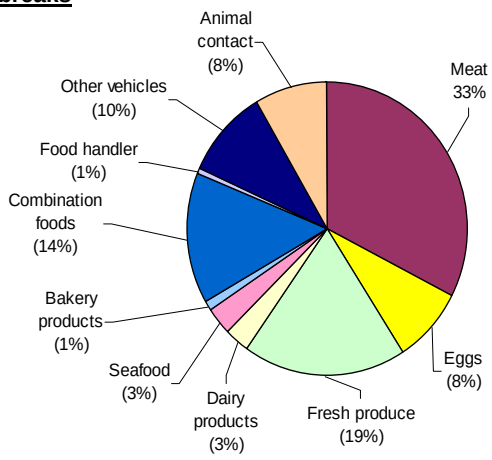


Figure 6. Vehicles for non-typhoidal salmonellosis outbreaks (U.S. And Canada only) with known/suspected vehicles.

Outbreaks



Cases

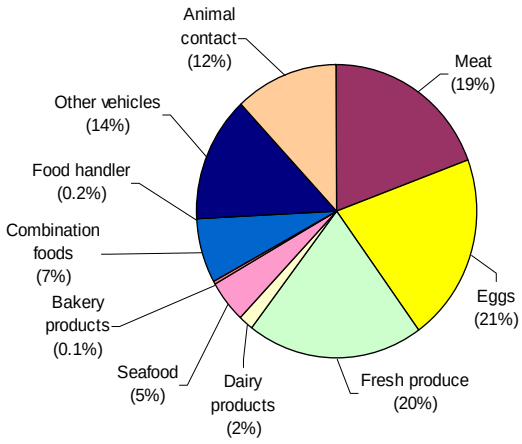


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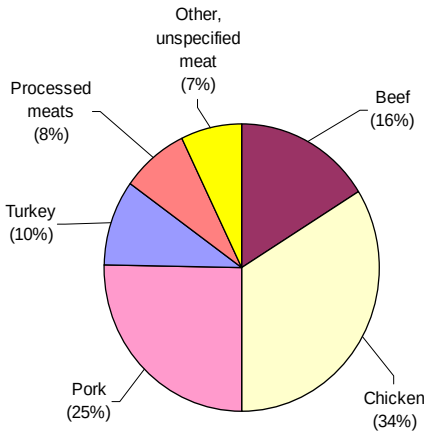
Table 7. Outbreaks and cases of salmonellosis associated with different types of meat (all outbreaks).

Outbreaks



Cases

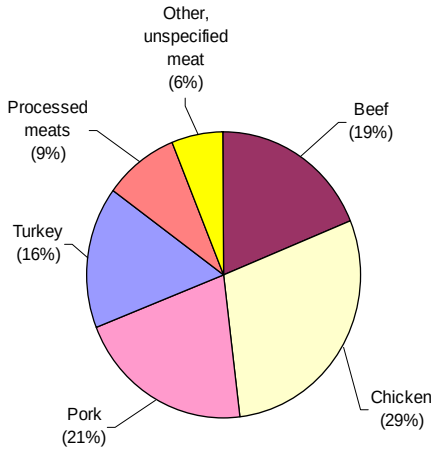
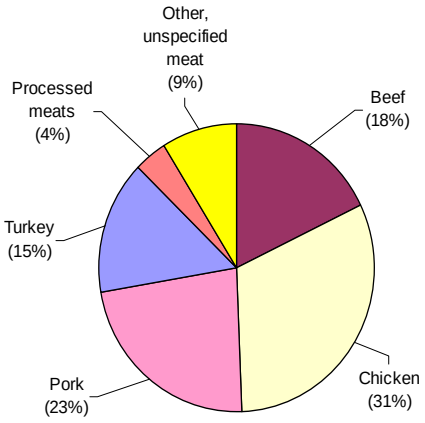


Table 8. Outbreaks and cases of salmonellosis in the US and Canada associated with different types of meat (U.S. and Canada only).

Outbreaks



Cases

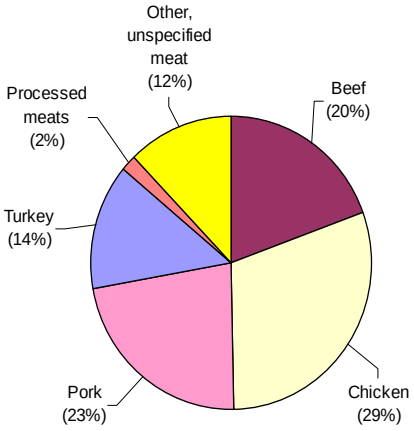


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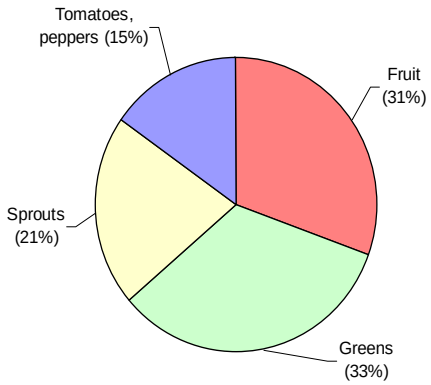
Figure 9. Outbreaks and cases of salmonellosis associated with different types of fresh produce.

Outbreaks



Cases

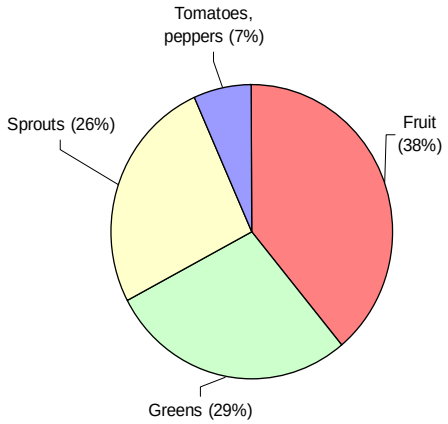
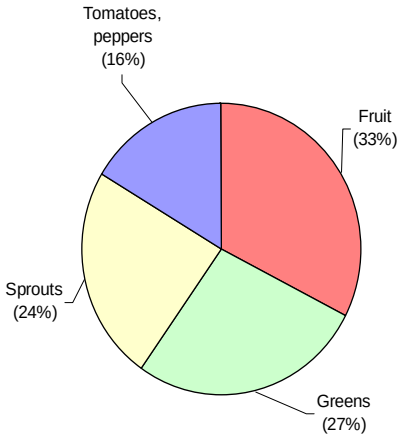


Figure 10. Outbreaks and cases of salmonellosis in the US and Canada associated with different types of fresh produce.

Outbreaks



Cases

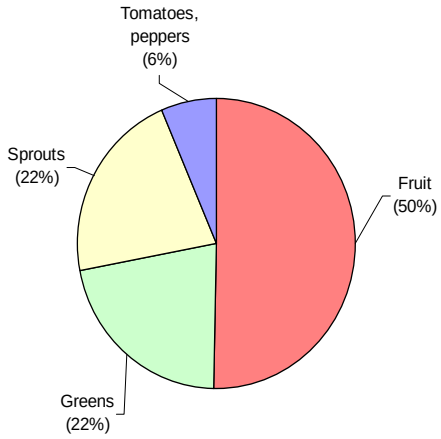


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Table 1. Large outbreaks (>127 cases) of *Salmonella* occurring from 2007 to 2013.

Year	# Cases	Serotype	Location	Vehicle	Reference(s)
2012	4185	Typhi	Zimbabwe	well water	(*45*)
2010	1939	Enteritidis	U.S.	eggs	(*28*)
2012	866	Thompson	Netherlands	smoked salmon	(*62*)
2008–09	714	Typhimurium	U.S.	peanut butter	(*26*)
2007	695	Enteritidis	Bosnia	chicken, mayonnaise	(*12*)
2011–13	684	Stanley	Europe	turkey	(*58*)
2008	594	Javiana	U.S.	watermelon	(*33*)
2008–09	577	Typhi	Uganda	water	(*109*)
2010	554	I 4,[5],12:i:-	France	beef burgers	(*123*)
2009	489	Enteritidis	England	eggs	(*87*)
2008–09	470	Typhimurium	UK	feeder mice	(*77*)
2012	425	Bareilly, Nchanga	U.S.	raw tuna	(*34*)
2008–11	376	Typhimurium	U.S.	aquatic frogs	(*105*)
2011	337	I 4,[5],12:i:-	France	dried pork sausage	(*71*)
2009	327	Enteritidis	England	egg cress rolls	(*48*)
2009	303	Typhi	Malawi	water	(*128*)
2010	272	Bareilly	UK	mung bean sprouts	(*134*)
2009–10	272	Montevideo	U.S.	salami	(*90*)
2011	262	Enteritidis	UK	eggs	(*7*)
2012	261	Newport, Typhimurium	U.S.	cantaloupe	(*35*)
2009	256	Saintpaul	U.S.	alfalfa sprouts	(*27*;*33*)
2006–07	224	Typhimurium	Netherlands	hard cheese, raw milk	(*137*)
2007	216	Enteritidis	Singapore	cream cakes	(*43*)
2008	205	Typhimurium	Switzerland	pork	(*127*)
2009	200	Newport	U.S.	unknown	(*33*)
2012	195	Infantis, Newport, Lille	U.S.	baby chicks	(*37*)
2011	190	Heidelberg	U.S.	chicken liver	(*32*)
2009	184	Enteritidis	U.S.	unknown	(*33*)
2008	179	Typhimurium	UK	egg sandwiches	(*20*)
2010–11	177	Poona	Spain	infant formula	(*59*)
2008	176	Braenderup	Japan	eggs in boxed lunches	(*107*)
2010	172	Typhimurium	Denmark	pork products	(*93*)
2010	168	Typhimurium	Australia	pork products	(*115*)
2010	159	Mbandaka	Austria	eggs, contaminated feed	(*5*)
2008	146	Rubislaw	U.S.	meat	(*33*)
2009	145	Typhimurium	U.S.	shredded lettuce	(*33*)
2012	140	Braenderup	U.S., Canada	mangoes	(*36*)
2010	140	I 4,[5],12:i:-	U.S.	alfalfa sprouts	(*33*)
2011	136	Heidelberg	U.S.	ground turkey	(*29*)
2010	136	Java	UK	salad vegetables	(*68*)
2008	135	Typhimurium	U.S.	pet turtles	(*22*)
2009	133	Enteritidis	U.S.	pudding	(*33*)
2010–11	132	Paratyphi B	U.S.	pet turtles	(*141*)
2009	132	Blegdam	China	pork, chicken	(*79*)
2012–13	128	Heidelberg	U.S.	chicken	(*40*)

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Table 3. *Salmonella* serotypes and associated outbreaks, cases, and vehicles (2007–2013).

Serotype	Outbreaks	Cases	Vehicles
Aberdeen	1	4	chicken, rice
Agbeni	1	8	multiple foods
Agona	3	146	papayas, sediment in oven
Altona	1	68	chicks and ducklings
Anatum	6	114	chicken, pork, salads,
Anfo	1	17	unknown
Baildon	1	80	restaurant, Mexican style food
Bareilly	2	697	bean sprouts, raw tuna
Barranquilla	2	49	bass, tuna
Berta	4	68	eggs, ground turkey
Birkenhead	1	37	unknown
Blegdam	1	132	chicken, pork
Blockley	1	9	mole, pasta with tomato sauce
Bovismorbificans	3	76	bass, pasta salad, tahini
Braenderup	11	425	barbecued pork, eggs in boxed lunches, green salad, jalapeno peppers, mangoes, tomatoes
Bredeney	1	41	peanut butter
Carrau	1	53	melon
Chester	4	94	chicken, fresh chillies head cheese,
Cubana	3	25	alfalfa sprouts, onion sprouts
Derby	1	5	roast pork
Eastbourne	1	23	unknown
Enteritidis	130	6232	alfalfa sprouts, beef, bread, cake, canoli, chicken, cream, eggs, food handler, fried rice, guacamole, ice cream, lamb, lasagna, mayonnaise, "Mexican" food, pasta, pine nuts, pork, potato salad, pudding, salad dressing, salads, stuffed shrimp, tortilla chips, turkey ham, vegetable dishes (ethnic)
Give	2	60	carnitas (meat), cold pasta salad, pork
Goldcoast	2	139	pork products
Group B	1	15	guacamole
Hadar	7	163	chicks, turkey meat
Hartford	3	119	salsa, restaurant Mexican style
Heidelberg	28	863	cheesecake, chicken, chicken liver, eggs, ice cream, macaroni and cheese, pork barbecue, pureed food, salmon, taco, turkey
Hindmarsh	1	32	pork, beef
Hvittingfoss	2	119	lettuce, salad vegetables
I 4,[5],12:i:-	13	1325	alfalfa sprouts, chicken, feeder rodents, guacamole, hamburger, pet turtles, pork sausage, pudding
Infantis	18	625	baked beans, bakery products, chicken, chicks, cole slaw, dry dog food, duck parfait, fruit, meatballs, pork barbecue, prawn salad, salads, thickened fluid, vegetable dip
Java	4	283	burritos, cheese, playground sand, salads
Javiana	12	858	cantaloupe, chicken, onion, pork, tomatoes, watermelon
Johannesburg	2	42	chicks, ducklings, pork
Kiambu	1	10	unknown
Litchfield	4	112	fish, fruit, melon
Lille	1	195	chicks
Mbandaka	1	159	eggs
Miami	4	41	salad
Montevideo	17	1031	beef, cheese, chicken, chicks, fish, pepper in salami, pork, supplement marketed to women, tacos
Muenchen	7	119	beans, blueberries, deli sandwich, ham, salsa
Muenster	2	29	goat cheese unpasteurized, pork
Nchanga	1	425	raw tuna

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Serotype	Outbreaks	Cases	Vehicles
Newport	41	1610	beef, blueberries, burrito, cantaloupe, chicks, lettuce, green chile, guacamole, jalapeno peppers, pickles, pork, raw milk, sprouts, tomatoes, turkey, turtles, watermelon
Ohio	2	20	chicken
Oranienburg	9	232	alfalfa sprouts, raw milk cheese
Panama	3	70	cantaloupe, fruit salad, orange juice
Paratyphi	4	208	fish, pet turtles
Pomona	2	115	pet turtles
Poona	5	285	infant formula, pet turtles
Potsdam	1	17	unknown
Putten	1	9	raw beef
Reading	2	132	lettuce
Rissen	1	87	ground white pepper
Rubislaw	1	146	meat
Saintpaul	13	459	alfalfa sprouts, beef, chicken, cucumbers, fried ice cream, mangoes, pawpaw, salmon, tomatoes, turkey, watermelon
Sandiego	2	100	pet turtles
Schwarzengrund	1	9	potato salad
Senftenberg	1	14	tea with fennel seeds
Singapore	5	70	chicken, eggs, fried ice cream
Stanley	2	716	salads, turkey
Strathcona	1	57	tomatoes
Subspecies IIIa	2	14	turkey
Subspecies IV	1	19	gravy contaminated by bearded dragons
Tennessee	2	30	bearded dragon, person to person
Thompson	6	891	eggs, smoked salmon
Typhi	8	5201	food handler, mamey pulp, milk products, water
Typhimurium	281	7197	alfalfa sprouts, animal contact (frogs, hedgehogs, turtles), bakery products, beef, cake, cantaloupe, cheese (raw milk), chicken, custard, duck parfait, eggs, fried ice cream, fried rice, head cheese, laboratory exposure, lettuce, mayonnaise, meat, Mexican food, milkshake, mixed nuts, pasta, peanut butter, person to person, pork, prawn dumplings, pudding, raw flour, rice, salads, salami, sausage, tap water, turkey (RTE), Vietnamese food, vitaminised food, watermelon
Uganda	4	41	carnitas (meat), salsa
Urbana	1	14	unknown
Virchow	5	40	chicken curry, eggs, pork
Wangata	1	3	unknown
Weltevreden	2	49	fish

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Table 4. *Salmonella* serotypes and associated outbreaks, cases, and vehicles in the U.S. and Canada (2007–2013).

Serotype	Outbreaks	Cases	Vehicles
Aberdeen	1	4	chicken, rice
Agbeni	1	8	multiple foods
Agona	2	112	papayas
Altona	1	68	chicks and ducklings
Anatum	3	94	chicken, pork
Anfo	1	17	unknown
Baildon	1	80	Mexican style food, restaurant
Bareilly	1	425	raw tuna
Barranquilla	2	49	bass, tuna
Berta	3	53	ground turkey
Blockley	1	9	mole, pasta with tomato sauce
Bovismorbificans	3	76	bass, pasta salad, tahini
Braenderup	10	289	barbecued pork, green salad, jalapeno peppers, mangoes, tomatoes
Bredeney	1	41	peanut butter
Carrau	1	53	melon
Chester	3	80	chicken, head cheese
Cubana	3	25	alfalfa sprouts, onion sprouts
Derby	1	5	roast pork
Eastbourne	1	23	unknown
Enteritidis	113	4100	alfalfa sprouts, beef, canoli, chicken, cream, eggs, food handler, fried rice, guacamole, ice cream, lamb, lasagna, mayonnaise, "Mexican" food, pasta, pine nuts, pork, potato salad, pudding, salad dressing, salads, stuffed shrimp, tortilla chips, turkey ham, vegetable dishes
Give	1	50	carnitas (meat), pork
Group B	1	15	guacamole
Hadar	7	163	chicks, turkey meat
Hartford	3	119	salsa, restaurant Mexican style
Heidelberg	27	856	cheesecake, chicken, chicken liver, eggs, ice cream, macaroni and cheese, multiple foods, pork barbecue, pureed food, salmon, taco, turkey
Hvittingfoss	2	119	lettuce, salad vegetables
I 4,[5],12:i:-	9	320	alfalfa sprouts, chicken, feeder rodents, guacamole, pet turtles, pudding
Infantis	12	501	baked beans, chicks, dry dog food, fruit, meatballs, pork barbecue, salads, vegetable dip
Java	2	72	cheese, burritos
Javiana	12	858	cantaloupe, chicken, onion, pork, tomatoes, watermelon
Johannesburg	1	28	chicks, ducklings
Kiambu	1	10	unknown
Litchfield	3	36	fruit, melon
Lille	1	195	chicks
Miami	4	41	salad
Montevideo	14	933	beef, cheese, chicken, chicks, fish, pepper in salami, pork, dietary supplement, tacos
Muenchen	6	103	beans, blueberries, deli sandwich, salsa
Muenster	2	29	goat cheese unpasteurized, pork
Nchanga	1	425	raw tuna
Newport	39	1380	beef, blueberries, burrito, cantaloupe, chicks, lettuce, green chile, guacamole, jalapeno peppers, pickles, pork, raw milk, sprouts, tomatoes, turkey, turtles, watermelon
Ohio	2	20	chicken
Oranienburg	8	111	alfalfa sprouts,
Panama	2	70	cantaloupe, fruit salad
Paratyphi	3	208	fish, pet turtles
Pomona	2	115	pet turtles
Poona	4	108	pet turtles

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Serotype	Outbreaks	Cases	Vehicles
Potsdam	1	17	unknown
Reading	1	26	unknown
Rissen	1	87	ground white pepper
Rubislaw	1	146	meat
Saintpaul	9	425	alfalfa sprouts, beef, chicken, cucumbers, tomatoes, turkey, watermelon
Sandiego	2	91	pet turtles
Schwarzengrund	1	9	potato salad
Subspecies IIIa	2	14	turkey
Subspecies IV	1	19	gravy contaminated by bearded dragons
Tennessee	1	12	person to person
Thompson	5	25	eggs
Typhi	2	14	mamey pulp
Typhimurium	61	2516	animal contact (frogs, hedgehogs, turtles), bakery products, beef, cantaloupe, chicken, eggs, head cheese, laboratory exposure, lettuce, meat, Mexican food, peanut butter, pork, salads, sausage, sprouts
Uganda	4	41	carnitas (meat), salsa

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Table 7. Reported vehicles and associated outbreaks, cases, and serotypes (2008–2013).

Vehicle	Outbreaks	Cases	Serotypes
Animal contact (bandicoot, chicks, ducklings, feeder rodents, hedgehogs)	11	1182	Altona, Hadar, I 4,[5],12,i:-, Infantis, Java, Johannesburg, Lille, Montevideo, Newport, Typhimurium
Animal contact (bearded dragons, frogs, turtles)	14	1062	I 4,[5],12,i:-, Newport, Paratyphi, Pomona, Poona, Sandiego, Subspecies IV, Tennessee, Typhimurium
Bakery products (bagels, bread, cake, canoli)	13	364	Enteritidis, Infantis, Typhimurium
Beef	22	1203	Enteritidis, Hindmarsh, I 4,[5],12:i:-, Montevideo, Newport, Putten, Saintpaul, Typhimurium
Chicken (meat)	48	1972	Aberdeen, Anatum, Blegdam, Chester, Enteritidis, Heidelberg, I 4,[5],12:i:-, Infantis, Javiana, Montevideo, Ohio, Saintpaul, Singapore, Typhimurium, Virchow
Combination/multiple foods (baked beans, burrito, fried rice, lasagna, pasta, pizza, pureed food, sandwiches, spring rolls, tacos)	43	1023	Aberdeen, Agbeni, Baildon, Blockley, Bovismorbificans, Enteritidis, Hartford, Heidelberg, Infantis, Java, Javiana, Muenchen, Newport, Schwarzengrund, Typhimurium
Dairy products (cheese, cream, ice cream, milk)	12	679	Chester, Enteritidis, Java, Heidelberg, I 4,[5],12:i:-, Montevideo, Muenster, Newport, Oranienburg, Typhimurium
Eggs & egg dishes (aioli, custard, mayonnaise, mousse, omelet, pudding, tiramisu)	132	6500	Berta, Braenderup, Enteritidis, Heidelberg, Mbandaka, Saintpaul, Singapore, Thompson, Typhimurium, Virchow
Fish & seafood (ahi, barramundi, bass, prawns, red snapper, salmon, shrimp, sushi, tuna)	14	1607	Bareilly, Barranquilla, Bovismorbificans, Enteritidis, Heidelberg, Infantis, Litchfield, Montevideo, Nchanga, Paratyphi B, Saintpaul, Thompson, Typhimurium, Weltvreden
Food handler	6	913	Enteritidis, Typhi
Formula, infant	1	177	Poona
Fruit (blueberries, cantaloupe, mamey, mango, orange juice, papayas, paw paw, watermelon)	19	1383	Agona, Braenderup, Carrau, Infantis, Javiana, Litchfield, Muenchen, Newport, Panama, Saintpaul, Typhi, Typhimurium
Greens (cilantro, coleslaw, lettuce, salads)	21	1022	Anatum, Braenderup, Enteritidis, Give, Hvittingfoss, Infantis, Java, Miami, Montevideo, Newport, Reading, Stanley, Typhimurium
Meat, other (barbecue, duck, lamb, taco meat, unspecified, wild boar)	11	428	Anatum, Enteritidis, Heidelberg, Infantis, Montevideo, Rubislaw, Typhimurium, Uganda
Meat, processed (ham, head cheese, salami, sausage)	11	572	Chester, Enteritidis, I 4,[5],12:i:-, Muenchen, Typhimurium
Miscellaneous (black pepper, fennel tea, occupational exposure, pet food, pickles, red pepper, sediment in oven, supplement, thickened fluid, vitaminised food, white pepper)	10	397	Agona, Infantis, Montevideo, Newport, Rissen, Senftenberg, Typhimurium
Nuts, chips, peanut butter	5	824	Bredeney, Enteritidis, Typhimurium
Person to person	2	15	Tennessee, Typhimurium
Pork	36	1425	Anatum, Blegdam, Braenderup, Derby, Enteritidis, Give, Goldcoast, Heidelberg, Hindmarsh, Infantis, Javiana, Johannesburg, Montevideo, Muenster, Newport, Typhimurium
Sauce (dips, guacamole, salad dressing, salsa, tahini)	15	340	Bovismorbificans, Enteritidis, Group B, Hartford, I 4,[5],12:i:-, Infantis, Muenchen, Newport, Uganda
Sprouts (alfalfa, bean, clover, onion)	13	958	Bareilly, Cubana, Enteritidis, I 4,[5],12:i:-, Newport, Oranienburg, Saintpaul, Typhimurium
Turkey (meat)	13	1022	Berta, Enteritidis, Hadar, Heidelberg, Newport, Saintpaul, Stanley, Subspecies IIIa
Water, drinking, well	4	5168	Typhi
Vegetables (chillis, cucumbers, peppers, tomatoes)	10	244	Braenderup, Chester, Javiana, Newport, Saintpaul, Strathcona

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Table 8. Reported vehicles and associated outbreaks, cases, and serotypes in the U.S. and Canada (2008–2013).

Vehicle	Outbreaks	Cases	Serotypes
Animal contact (chicks, ducklings, feeder rodents, hedgehogs)	9	637	Altona, Hadar, I 4,[5],12,i:-, Infantis, Johannesburg, Lille, Montevideo, Typhimurium
Animal contact (bearded dragons, frogs, turtles)	12	1033	I 4,[5],12,i:-, Newport, Paratyphi, Pomona, Poona, Sandiego, Subspecies IV, Typhimurium
Bakery products (bagels, canoli)	3	16	Enteritidis, Typhimurium
Beef	14	481	Enteritidis, Montevideo, Newport, Saintpaul, Typhimurium
Chicken (meat)	26	786	Aberdeen, Anatum, Chester, Enteritidis, Heidelberg, I 4,[5],12:i:-, Javiana, Montevideo, Ohio, Saintpaul, Typhimurium
Combination/multiple foods (baked beans, burrito, fried rice, lasagna, pasta, pizza, pureed food, sandwiches, spring rolls, tacos)	43	1023	Aberdeen, Agbeni, Baildon, Blockley, Bovismorbificans, Enteritidis, Hartford, Heidelberg, Infantis, Java, Javiana, Muenchen, Newport, Schwarzengrund, Typhimurium
Dairy products (cheese, cream, ice cream, milk)	8	305	Chester, Enteritidis, Heidelberg, I 4,[5], 12:i:-, Java, Montevideo, Newport
Eggs & egg dishes (custard, mayonnaise, mousse, omelet, pudding, sandwiches)	20	2498	Enteritidis, Heidelberg, I 4,[5], 12:i:-, Thompson
Fish & seafood (ahi, barramundi, bass, red snapper, salmon, shrimp, sushi, tuna)	7	561	Bareilly, Barranquilla, Bovismorbificans, Enteritidis, Heidelberg, Nchanga, Paratyphi B
Food handler	1	15	Enteritidis
Fruit (blueberries, cantaloupe, mamey, mango, papayas, watermelon)	15	1311	Agona, Braenderup, Carrau, Infantis, Javiana, Litchfield, Muenchen, Newport, Panama, Saintpaul, Typhi, Typhimurium
Greens (cilantro, coleslaw, lettuce, salads)	13	572	Enteritidis, Hvittingfoss, Infantis, Java, Miami, Montevideo, Newport, Typhimurium
Meat, other (barbecue, lamb, taco meat)	7	300	Anatum, Enteritidis, Infantis, Montevideo, Rubislaw, Typhimurium, Uganda
Meat, processed (head cheese, sausage)	3	44	Chester, Typhimurium
Miscellaneous (black pepper; occupational exposure; pet food; pickles, red pepper, white pepper)	5	185	Infantis, Montevideo, Newport, Rissen, Typhimurium
Nuts, tortilla chips, peanut butter	4	805	Bredeney, Enteritidis, Typhimurium
Person to person	1	12	Tennessee
Pork	19	593	Anatum, Braenderup, Derby, Enteritidis, Give, Heidelberg, Infantis, Javiana, Montevideo, Muenster, Newport, Typhimurium
Sauce (dips, guacamole, salad dressing, salsa, tahini)	15	340	Bovismorbificans, Enteritidis, Group B, Hartford, I 4,[5],12:i:-, Infantis, Newport, Uganda
Sprouts (alfalfa, bean, clover, onion)	11	562	Cubana, Enteritidis, I 4,[5], 12:i:-, Newport, Oranienburg, Saintpaul, Typhimurium
Turkey (meat)	12	338	Berta, Enteritidis, Hadar, Heidelberg, Newport, Saintpaul, Subspecies IIIa
Vegetables (chillis, cucumbers, peppers, tomatoes)	8	173	Braenderup, Javiana, Newport, Saintpaul

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APPENDIX:
Chronological List of *Salmonella* Outbreaks with a Certain or Probable Vehicle (2008–2013)

Year	Serotype	Location	Cases	Hosp	Deaths	Vehicle	Reference(s)
2013	Saintpaul	US: 18 states	73	14	0	Cucumbers	(*149*)
2012–2013	Heidelberg	US: 13 states	128	32	0	Chicken	(*44*)
2012–2013	Poona, strain B	US: 9 states	38	5	0	Animal contact: pet turtles	(*142*)
2012–2013	Typhimurium	US: 6 states	22	7	0	Beef, ground, raw	(*43*)
2012–2013	Typhimurium	US: 13 states, DC	44	9		Animal contact: pet turtles	(*142*)
2011–2013	Pomona, strain A	US: 11 states	19	4	0	Animal contact: pet turtles	(*142*)
2011–2013	Pomona, strain B	US: 26 states	96	15	0	Animal contact: pet turtles	(*142*)
2011–2013	Poona, strain A; Sandiego strain C	US: 22 states	55	12	0	Animal contact: pet turtles	(*142*)
2011–2013	Sandiego strain A; Newport	US: 17 states	93	13	0	Animal contact: pet turtles	(*142*)
2011–2013	Stanley	Europe: 10 countries	684			Turkey; other foods?	(*53*)
2011–2013	Typhimurium	US: 9 states	23	7	1	Animal contact: hedgehogs	(*90*; *142*)
2012	I 4,[5],12:i:-	US: 4 states	19	3		Animal contact: pet turtles	(*142*)
2012	Anatum	Australia	4	0	0	Salads	(*108*)
2012	Bareilly; Nchanga	US: 28 states	425	55	0	Tuna, raw, scraped, ground	(*35*)
2012	Braenderup	US: 15 states; Canada	140	33	0	Mangoes	(*38*)
2012	Bredeney	US: 20 states	41	10	0	Peanut butter	(*88*)
2012	Enteritidis	Slovakia	43	4	0	Eggs	(*75*)
2012	Enteritidis	US: 9 states	46	12	0	Beef, ground	(*36*)
2012	Give	Australia	10	1		Salad, pasta cold	(*108*)
2012	Hadar	US: 11 states	55	13	0	Animal contact: chicks	(*39*)
2012	Infantis; Newport; Lille	US: 27 states	195	34	2	Animal contact: chicks	(*41*)
2012	Montevideo	US: 23 states	93	21	1	Animal contact: chicks	(*40*)
2012	Muenchen	Australia	16	1		Ham	(*108*)
2012	Newport; Typhimurium	US: 24 states	261	94	3	Cantaloupe	(*37*)
2012	Oranienburg	France	121	13		Cheese, raw sheep milk	(*148*)
2012	Sandiego, strain B	US: 3 states	7	1	0	Animal contact: pet turtles	(*42*)
2012	Thompson	Netherlands	866	38		Salmon, smoked	(*55*)
2012	Typhi	Zimbabwe	4185	1788	2	Water, well	(*46*)
2012	Typhimurium	Australia	22	0		Egg whites, raw	(*108*)
2012	Typhimurium	Australia	20	3		Mayonnaise, raw egg	(*108*)
2012	Typhimurium	Australia	20	2	0	Eggs Benedict	(*95*)
2012	Typhimurium	Australia	18	1	0	Eggs, raw	(*108*)
2012	Typhimurium	Australia	14	2		Ice cream, fried	(*108*)
2012	Typhimurium	Australia	11	0	0	Egg butter, raw, with rolls	(*108*)
2012	Typhimurium	Australia	10	1		Mayonnaise, raw egg	(*108*)
2012	Typhimurium	Australia	10	3		Chicken doner kebab	(*108*)
2012	Typhimurium	Australia	9	0	0	Ice cream, fried	(*108*)
2012	Typhimurium	Australia	7	3		Eggs	(*108*)
2012	Typhimurium	Australia	5	0	0	Eggs	(*108*)
2012	Typhimurium	Australia	5	1		Ice cream, fried	(*108*)
2012	Typhimurium	Australia	4	2	0	Beef with egg and bacon	(*108*)
2012	Typhimurium	Australia	4	0	0	Egg, raw, with chocolate cake	(*108*)
2012	Typhimurium monophasic	Sweden	34			Lettuce, washed	(*5*)
2011–2012	I 4,[5],12:i:-	US: 22 states	46	6	0	Animal contact: feeder rodents	(*125*)
2011–2012	Infantis	US; 20 states; Canada	49	10	0	Dog food, dry	(*34*)
2011	4,[5],12:i:-	France	337			Pork sausage, dried	(*59*)
2011	Agbeni	Canada	8	1	0	Multiple foods	(*127*)
2011	Agona	New Zealand	34	1		Bones; Shells; Sediment in earth oven	(*140*)
2011	Agona	US: 25 states	106	10	0	Papayas	(*25*)
2011	Altona	US: 20 states	68	19	0	Animal contact: chicks, ducklings	(*26*)
2011	Bovismorbificans	US: 7 states	23	0	0	Tahini	(*10*)
2011	Enteritidis	France	36	2		Wild boar meat	(*147*)
2011	Enteritidis	Poland	34	4		Eggs	(*146*)
2011	Enteritidis	Singapore	14	8	0	Bread, omelette floss	(*128*)
2011	Enteritidis	UK	262			Eggs	(*145*)
2011	Enteritidis	US: 10 states	68	21	0	Restaurant food, Mexican-style	(*31*)
2011	Enteritidis	US: 5 states	43	2	0	Nuts, pine, Turkish	(*28*)
2011	Enteritidis	US: 5 states	25	3	0	Sprouts, alfalfa and spicy	(*24*)
2011	Heidelberg	US: 34 states	136	37	1	Turkey, ground	(*27*)
2011	Heidelberg	US: 6 states	190	30	0	Chicken livers, kosher, broiled	(*29*)
2011	Hindmarsh	Georgia	32	2	0	Meat (pork and beef)	(*79*)
2011	Infantis	Australia	2	2	0	Prawn salad rolls	(*108*)
2011	Johannesburg	US: 15 states	28	9	0	Animal contact: chicks, ducklings	(*26*)

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Chronological List of *Salmonella* Outbreaks with a Certain or Probable Vehicle (2008–2013)

Year	Serotype	Location	Cases	Hosp	Deaths	Vehicle	Reference(s)
2011	Newport	Germany; Netherlands	124	28	0	Sprouts, bean	(*116*)
2011	Panama	US: 10 states	20	3	0	Cantaloupe	(*23*)
2011	Saintpaul	Australia	3	0		Mango smoothie	(*109*)
2011	Singapore	Australia	46	2		Chicken, roast, served cold	(*106*)
2011	Singapore	Australia	10	0		Chicken, roast, served cold	(*106*)
2011	Strathcona	Denmark; Germany; Austria	57			Tomatoes from Italy	(*97*;*123*)
2011	Typhimurium	Australia	85	17		Egg butter, raw, with rolls	(*106*)
2011	Typhimurium	Australia	84	19		Mayonnaise, raw egg	(*106*)
2011	Typhimurium	Australia	49	6		Eggs	(*106*)
2011	Typhimurium	Australia	48	11		Eggs	(*105*)
2011	Typhimurium	Australia	43	19		Eggs, custard	(*106*)
2011	Typhimurium	Australia	41	7		Mayonnaise, raw egg	(*110*)
2011	Typhimurium	Australia	37	11		Eggs	(*110*)
2011	Typhimurium	Australia	27	7		Multiple foods	(*110*)
2011	Typhimurium	Australia	26	6		Mayonnaise, raw egg	(*106*)
2011	Typhimurium	Australia	18	3		Chicken pate	(*106*)
2011	Typhimurium	Australia	17	1		Apple turnover	(*106*)
2011	Typhimurium	Australia	15	2		Ice cream, fried	(*105*)
2011	Typhimurium	Australia	15	3		Bakery product - cannoli	(*106*)
2011	Typhimurium	Australia	15	6		Pork, eggs, Vietnamese dish	(*106*)
2011	Typhimurium	Australia	15	5		Egg butter, raw, with rolls	(*106*)
2011	Typhimurium	Australia	14	1		Egg, raw, chocolate mousse	(*109*)
2011	Typhimurium	Australia	13	1		Egg, raw, tiramisu	(*109*)
2011	Typhimurium	Australia	11	0		Egg, raw, tiramisu	(*109*)
2011	Typhimurium	Australia	11	1		Eggs raw, salad dressing	(*106*)
2011	Typhimurium	Australia	10	0		Eggs, raw custard	(*106*)
2011	Typhimurium	Australia	9	5		Mayonnaise, raw egg (potato salad)	(*105*)
2011	Typhimurium	Australia	9	1		Chicken, lamb kebabs	(*106*)
2011	Typhimurium	Australia	8	0		Eggs	(*105*)
2011	Typhimurium	Australia	6	0		Eggs, raw	(*109*)
2011	Typhimurium	Australia	6	2		Ice cream, fried	(*106*)
2011	Typhimurium	Australia	6	2		Egg wash	(*106*)
2011	Typhimurium	Australia	5	1		Pork, spit roast	(*105*)
2011	Typhimurium	Australia	4	0		Mousse, chocolate, raw egg	(*110*)
2011	Typhimurium	Australia	4	2		Eggs	(*109*)
2011	Typhimurium	Australia	4	2		Prawn dumplings with egg	(*105*)
2011	Typhimurium	Australia	3	0		Mayonnaise, raw egg	(*109*)
2011	Typhimurium	Australia	3	0		Eggs	(*105*)
2011	Typhimurium	Australia	3	1		Chicken sushi	(*106*)
2011	Typhimurium	Australia	2	0		Eggs, raw, chocolate mousse	(*105*)
2011	Typhimurium	Australia	2	0		Muffin batter, raw (eggs)	(*105*)
2011	Typhimurium	Australia	2	2		Pancake batter, raw (eggs)	(*105*)
2011	Typhimurium	Austria	25			Eggs in boxed lunches	(*134*)
2011	Typhimurium	Denmark	22			Pork, smoked tenderloin	(*102*)
2011	Typhimurium	US: 7 states	20	8	0	Beef, ground	(*32*)
2011	Typhimurium; Infantis	Australia	65	0		Duck parfait	(*109*)
2011	Typhimurium RNDC	Scotland	3	0	0	Person to person	(*92*)
2010–2011	Goldcoast	Hungary	33			Pork products	(*54*)
2010–2011	Hadar	US: 10 states	12	3	0	Turkey burgers	(*22*)
2010–2011	Paratyphi B	US: 18 states	132		0	Animal contact: pet turtles	(*137*)
2010–2011	Paratyphi var Java	Spain	11			Animal contact: pet turtles	(*67*)
2010–2011	Poona	Spain	177			Infant formula, powdered	(*54*)
2010–2011	Typhimurium	Australia	13	3		Multiple foods	(*108*)
2010–2011	Typhimurium	US: 38 states	109	13	1	Laboratories: clinical, teaching	(*30*)
2008–2011	Typhimurium	US: 44 states	376	56	0	Animal contact: aquatic frogs	(*60*;*139*;*143*)
2010	4,[5],12:i:-	France	554	31	0	Beef, burgers	(*113*)
2010	4,12:i:-	France	110	20	0	Pork sausage, dried	(*12*)
2010	Anatum	US: FL	37	1	0	Chicken; Pork	(*33*)
2010	Baildon	US: 15 states	80	27	0	Restaurant, Mexican-style	(*20*)
2010	Bareilly	UK	272	32	1	Sprouts, mung bean	(*47*;*130*)
2010	Berta	US: multistate	35	2	0	Turkey, ground	(*33*)
2010	Braenderup	US: CA	20	0	0	Pork, BBQ	(*33*)
2010	Chester	Canada	33	8		Meat, head cheese	(*126*)
2010	Chester	US: multistate	44	7	0	Chicken, cheesy	(*33*)
2010	Cubana	US: multistate	3			Sprouts, alfalfa	(*33*)

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Year	Serotype	Location	Cases	Hosp	Deaths	Vehicle	Reference(s)
2010	Enteritidis	Austria	66			Eggs; Potato salad	(*70*)
2010	Enteritidis	Austria	34			Eggs	(*83*)
2010	Enteritidis	Germany	52	10	0	Mayonnaise; Salads; Food workers	(*133*)
2010	Enteritidis	Germany	14	3	0	Vegetable pasta salad	(*93*)
2010	Enteritidis	US: AL	11	4	0	Chicken	(*33*)
2010	Enteritidis	US: CA	15	1	0	Eggs (cream puffs)	(*33*)
2010	Enteritidis	US: CA	7	1	0	Eggs (fruit tart)	(*33*)
2010	Enteritidis	US: CO	29	4	0	Eggs	(*33*)
2010	Enteritidis	US: CT	13	3	0	Shrimp, stuffed	(*33*)
2010	Enteritidis	US: CT	6	0	0	Pork, roasted	(*33*)
2010	Enteritidis	US: CT	3	2	0	Cannoli	(*33*)
2010	Enteritidis	US: MI	4	2	0	Chicken salad	(*33*)
2010	Enteritidis	US: MN	7	1	0	Chile rellenos (eggs)	(*33*)
2010	Enteritidis	US: MN	7	0	0	Chips, tortilla	(*33*)
2010	Enteritidis	US: multistate	1939			Eggs	(*21*)
2010	Enteritidis	US: NY	3	1	0	Cannoli	(*33*)
2010	Enteritidis	US: OH	56	7	9	Chile rellenos	(*33*)
2010	Enteritidis	US: OR	73	3	0	Guacamole	(*33*)
2010	Enteritidis	US: PA	37	5	0	Lasagna, beef; Soup; Egg	(*33*)
2010	Enteritidis	US: PA	21	1	0	Chicken and rice	(*33*)
2010	Enteritidis	US: WI	24	8	0	Ice cream, homemade	(*33*)
2010	Give	US: CA	50	2	0	Pork, carnitas	(*33*)
2010	Group B	US: NY	15	2	0	Guacamole	(*33*)
2010	Hartford	US: 15 states	75	15	0	Restaurant, Mexican-style	(*20*)
2010	Heidelberg	US: CA	21	1	0	Chicken	(*33*)
2010	Heidelberg	US: GA	11	2	0	Cheesecake; Chile con queso	(*33*)
2010	Heidelberg	US: OH	6	5	0	Turkey	(*33*)
2010	Hvittingfoss	US: IL	102	28	0	Lettuce, salad vegetables	(*33*)
2010	I 4,[5],12:i:-	US: multistate	140	31	0	Sprouts, alfalfa	(*33*)
2010	I 4,5,12:i:-	Australia	4	1		Pork salami	(*110*)
2010	Infantis	Australia	26	5	2	Chicken, raw	(*107*)
2010	Infantis	Australia	22	5	2	Thickened fluid, chicken?	(*98*)
2010	Infantis	Australia	3	0	0	Bakery products	(*107*)
2010	Infantis	New Zealand	7			Pizza	(*82*)
2010	Infantis	US: GA	74	7	0	Beans, baked; Coleslaw; Pork	(*33*)
2010	Infantis	US: IA	6	6	0	Pork, Carnitas	(*33*)
2010	Infantis	US: IL	28	1	0	Cala; Fruit; Meatballs	(*33*)
2010	Infantis	US: MN	21	0	0	Salads	(*33*)
2010	Java	UK	136	8		Salad vegetables	(*58*)
2010	Javiana	US: MI	41	5	0	Potato salad (onion)	(*33*)
2010	Javiana	US: multistate	30	8	0	Tomatoes	(*33*)
2010	Javiana; Typhimurium	US: RI	16	2	0	Chicken salad	(*33*)
2010	Mbandaka	Austria	159			Eggs; Contaminated feed	(*1*)
2010	Montevideo	Germany	31			Supplement sold to women	(*124*)
2010	Newport	US: 11 states	44	7	0	Sprouts, alfalfa	(*19*)
2010	Newport	US: FL	6	0	0	Pork, roasted	(*33*)
2010	Newport	US: IA	39	5	0	Guacamole	(*33*)
2010	Newport	US: IL	6	5	0	Pickles	(*33*)
2010	Newport	US: IL	2	0	0	Guacamole	(*33*)
2010	Newport	US: MN	6	1	0	Blueberries	(*33*)
2010	Newport	US: multistate	9			Sprouts, clover	(*33*)
2010	Newport	US: RI	27	3	0	Tomato	(*33*)
2010	Newport	US: UT	10	1	0	Milk, unpasteurized	(*61*)
2010	Newport	US: WA	16	1	0	Tomatoes	(*33*)
2010	Ohio	US: NY	13	1	0	Chicken, roasted	(*33*)
2010	Paratyphi B	US: multistate	51			Fish: ahi	(*33*)
2010	Saintpaul	Australia	7	3	0	Salmon; Couscous	(*107*)
2010	Saintpaul	US: MI	17	11	0	Watermelon	(*33*)
2010	Saintpaul	US: NY	9	1	0	Chicken, curry; Kebabs	(*33*)
2010	Singapore	Australia	5	0	0	Eggs	(*107*)
2010	Subspecies IIIa	US: WA	5	4	0	Turkey	(*33*)
2010	Thompson	US: AK	7	2	0	Hollandaise sauce (eggs)	(*33*)
2010	Typhi	US: NV, CA, OR	12	9	0	Mamey pulp, frozen	(*84*)
2010	Typhimurium	Australia	168	19	0	Eggs: aioli	(*107*)
2010	Typhimurium	Australia	47	5	0	Salads	(*107*)
2010	Typhimurium	Australia	45	8	0	Chicken; Hummus	(*107*)

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2010	Typhimurium	Australia	45	8	0	Chicken?; Food from kebab shop	(*129*)
2010	Typhimurium	Australia	43	2	0	Eggs: ice cream, homemade	(*107*)
2010	Typhimurium	Australia	34	1	0	Eggs, aioli	(*107*)
2010	Typhimurium	Australia	25	5	0	Eggs: aioli and Caesar salad	(*107*)
2010	Typhimurium	Australia	20	1	0	Bakery products	(*107*)
2010	Typhimurium	Australia	19	0	0	Nuts: peanut/cashew mixture	(*107*)
2010	Typhimurium	Australia	16	9	0	Rice, fried	(*107*)
2010	Typhimurium	Australia	15	1	0	Pasta salad	(*107*)
2010	Typhimurium	Australia	14	4	0	Eggs: fried ice cream	(*107*)
2010	Typhimurium	Australia	13	1	0	Eggs	(*107*)
2010	Typhimurium	Australia	12	1	0	Eggs: mayonnaise	(*107*)
2010	Typhimurium	Australia	10	2	0	Eggs: Hollandaise sauce	(*107*)
2010	Typhimurium	Australia	10	0	0	Pork roll	(*107*)
2010	Typhimurium	Australia	9	1	0	Eggs: tiramisu	(*107*)
2010	Typhimurium	Australia	9	0	0	Eggs: mayonnaise	(*107*)
2010	Typhimurium	Australia	9	5	0	Eggs: mousse	(*107*)
2010	Typhimurium	Australia	8	1	0	Eggs	(*107*)
2010	Typhimurium	Australia	8	3	0	Pork rolls	(*107*)
2010	Typhimurium	Australia	7	1	0	Eggs, scrambled	(*107*)
2010	Typhimurium	Australia	6	3	0	Eggs: tartare sauce	(*107*)
2010	Typhimurium	Australia	5	4	0	Eggs: mayonnaise	(*107*)
2010	Typhimurium	Australia	4	3	0	Pork, barbecued	(*107*)
2010	Typhimurium	Australia	4	0	0	Eggs: chocolate mousse	(*107*)
2010	Typhimurium	Australia	4	1	0	Chicken (restaurant)	(*107*)
2010	Typhimurium	Australia	4	2	0	Eggs	(*107*)
2010	Typhimurium	Australia	4	2	0	Milkshake, banana	(*107*)
2010	Typhimurium	Australia	3	0	0	Eggs: deep fried ice cream	(*107*)
2010	Typhimurium	Australia	2	1	0	Pork bun	(*107*)
2010	Typhimurium	Australia	2	2	0	Rice, broken	(*107*)
2010	Typhimurium	Australia	2	1	0	Eggs: in salmon patties	(*107*)
2010	Typhimurium	Denmark	172	26	8	Pork products, teewurst	(*77*)
2010	Typhimurium	Denmark	20	3	0	Salami (pork and venison)	(*78*)
2010	Typhimurium	Netherlands	90	43		Beef, raw: Ossenworst, Filet americain	(*56*)
2010	Typhimurium	New Zealand	21			Eggs, uncooked: mousse	(*82*)
2010	Typhimurium	New Zealand	4			Eggs: Spanish cream	(*82*)
2010	Typhimurium	UK; Ireland	88	8	1	Eggs, duck	(*57*;*100*)
2010	Typhimurium	US: CA	22	2	0	Beef, carne asada	(*33*)
2010	Typhimurium	US: CT	10	3	0	Bagels	(*33*)
2010	Typhimurium	US: MD	4	1	0	Salad	(*33*)
2010	Typhimurium	US: multistate	13			Salad, prepackaged	(*33*)
2010	Typhimurium	US: OH	64	1	0	Pork, smoked	(*33*)
2010	Typhimurium	US: SD	5	0	0	Sausage, smoked	(*33*)
2010	Uganda	US: GA	10	0	0	Carnitas; Salsa	(*33*)
2010		US: FL	17	2	0	Chicken	(*33*)
2010		US: FL	17	1	0	Pancit (noodle dish, may contain meat)	(*33*)
2010		US: FL	4	0	0	Pastry (egg)	(*33*)
2009–2010	Goldcoast	Italy	79			Pork	(*117*)
2009–2010	Montevideo	US: 44 states	272	52	0	Salami, with imported red and black pepper	(*33*;*74*)
2008–2010	I 4,[5],12:i:-	UK	470			Animal contact: feeder mice	(*63*)
2009	Blegdam	China	132			Pork; Chicken	(*64*)
2009	Carrau	US: multistate	53	4	1	Melon	(*33*)
2009	Chester	Australia	14	2	0	Chillies, fresh	(*104*)
2009	Cubana	US: MN	2	0	0	Sprouts, unspecified	(*33*)
2009	Derby	US: MI	5	0	0	Pork, roasted	(*33*)
2009	Enteritidis	England	489	6	2	Eggs	(*72*)
2009	Enteritidis	England	327			Egg cress rolls	(*141*)
2009	Enteritidis	Slovenia	38	3	0	Eggs	(*111*)
2009	Enteritidis	UK	81			Salad; Food worker?	(*121*)
2009	Enteritidis	US: CA	7	0	0	Eggs: cream puff	(*33*)
2009	Enteritidis	US: CA	4	1	0	Sauce, tartar; Mayonnaise, homemade; Vegetable-based salads	(*33*)
2009	Enteritidis	US: CT	7	2	0	Lasagna, vegetarian	(*33*)
2009	Enteritidis	US: IL	15	1	0	Pork, roasted	(*33*)
2009	Enteritidis	US: MD	27	6	0	Potato salad	(*33*)
2009	Enteritidis	US: NH	133	5	0	Pudding, contaminated blender	(*33*;*48*)
2009	Enteritidis	US: NH	45	1	0	Salads	(*33*)

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2009	Enteritidis	US: NJ	39	5	0	Chicken, marsala; Pork, other	(*33*)
2009	Enteritidis	US: NY	19	2	0	Malai Kofta (vegetarian)	(*33*)
2009	Enteritidis	US: NY	13	4	0	Lamb, chops	(*33*)
2009	Enteritidis	US: NY	12	2	0	Beef, corned, sandwich	(*33*)
2009	Enteritidis	US: NY	5	0	0	Dressing, Caesar	(*33*)
2009	Enteritidis	US: OH	22	1	0	Pasta, unspecified	(*33*)
2009	Enteritidis	US: OR	59	0	0	Eggs, scrambled	(*33*)
2009	Enteritidis	US: PA	12	0	0	Sauce, hollandaise	(*33*)
2009	Enteritidis	US: VA	19	2	0	Lasagna	(*33*)
2009	Enteritidis	US: VA	11	1	0	Rice, fried	(*33*)
2009	Enteritidis	US: WA	62	0	0	Eggs, scrambled	(*33*)
2009	Enteritidis	US: WA	5	3	0	Pork, unspecified	(*33*)
2009	Enteritidis	US: WA	2	0	0	Pad Thai	(*33*)
2009	Enteritidis	US: WI	14	2	0	Eggs, deviled	(*33*)
2009	Enteritidis	US: WV	21	9	2	Pork sausage	(*33*)
2009	Goldcoast	Hungary	60			Pork products; Pork cheese	(*69*)
2009	Heidelberg	US: CA	22	4	0	Specialty/Ethnic dishes	(*33*)
2009	Heidelberg	US: CA	16	0	0	Salmon, unspecified	(*33*)
2009	Heidelberg	US: multistate	35			Chicken	(*33*)
2009	Heidelberg	US: OR	26	8	0	Chicken	(*33*)
2009	Heidelberg; Infantis	US: TN	53	7	0	Pork, BBQ	(*33*)
2009	IIIa	US: CA	9	5	0	Turkey, other	(*33*)
2009	Infantis	US: CA	7	0	0	Sauce, vegetable dip	(*33*)
2009	Infantis	US: IL	17	6	0	Barbacoa (meat, usually beef or pork)	(*33*)
2009	Java	US: KS	2	0	0	Burritos	(*33*)
2009	Litchfield	Australia	76			Fish: barramundi	(*135*)
2009	Miami	US: MI	9	3	0	Salad, unspecified	(*33*)
2009	Montevideo	Australia	10	2	0	Unknown	(*104*)
2009	Montevideo	US: ND	88	0	0	Beef, roast	(*33*)
2009	Montevideo	US: ND	36	2	0	Taco meat	(*33*)
2009	Montevideo	US: SC	59	17	0	Pork, BBQ	(*33*)
2009	Muenchen	US: multistate	14		0	Blueberries	(*33*)
2009	Muenchen	US: WA	4	0	0	Sandwich, deli	(*33*)
2009	Newport	US: AZ	7	2	0	Peppers, jalapeno	(*33*)
2009	Newport	US: CO	43	10	0	Chile, green	(*33*)
2009	Newport	US: multistate	68	4	0	Beef, ground	(*33*)
2009	Newport	US: TN	13	6	0	Lettuce; Roast beef	(*33*)
2009	Newport	US: WA	6	1	0	Burrito, unspecified	(*33*)
2009	Oranienburg	US: multistate	25			Sprouts, alfalfa	(*33*)
2009	Putten	France	9	2	0	Beef, minced steaks, raw	(*85*)
2009	Saintpaul	Australia	17	3	0	Paw-paw	(*104*)
2009	Saintpaul	Australia	7	1	0	Ice cream, fried	(*104*)
2009	Saintpaul	US: 14 states	256	9	0	Sprouts, alfalfa	(*18*;*33*)
2009	Saintpaul	US: MI	21	7	0	Tomatoes	(*33*)
2009	Singapore	Australia	6	0	0	Chicken; Eggs	(*104*)
2009	Singapore	Australia	3	0	0	Eggs: fried ice cream	(*104*)
2009	Stanley	Australia	32	7	0	Salads	(*104*)
2009	subspecies IV	US: MN	19			Gravy contaminated by bearded dragons	(*87*)
2009	Typhi	France	16	15	0	Food handler, infected, asymptomatic	(*7*)
2009	Typhi	France	3	2		Food handler, infected, asymptomatic	(*86*)
2009	Typhi	Malawi; Mozambique	303	27	5	Water	(*120*)
2009	Typhimurium	Australia	71	14	0	Eggs: mayonnaise	(*73*;*104*)
2009	Typhimurium	Australia	40	5	0	Eggs: Hollandaise sauce	(*104*)
2009	Typhimurium	Australia	39	7	0	Eggs, scrambled	(*104*)
2009	Typhimurium	Australia	39	6	0	Mayonnaise, raw egg	(*104*)
2009	Typhimurium	Australia	33	9	0	Eggs: fried ice cream	(*104*)
2009	Typhimurium	Australia	31	9	0	Pork roll, Vietnamese	(*104*)
2009	Typhimurium	Australia	30	0	0	Eggs: aioli	(*49*;*104*)
2009	Typhimurium	Australia	20	0	0	Eggs: tiramisu	(*104*;*114*)
2009	Typhimurium	Australia	16	2	0	Eggs: tiramisu	(*104*)
2009	Typhimurium	Australia	9	1	0	Chicken or eggs	(*104*)
2009	Typhimurium	Australia	8	1	0	Chicken/pork rolls	(*104*)
2009	Typhimurium	Australia	7	0	0	Eggs: fried ice cream	(*104*)
2009	Typhimurium	Australia	6	2	0	Eggs: tiramisu	(*104*)
2009	Typhimurium	Australia	6	3	0	Eggs	(*104*)
2009	Typhimurium	Australia	5	0	0	Bakery product: zucchini bake	(*104*)

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2009	Typhimurium	Australia	4	0	0	Cake	(*104*)
2009	Typhimurium	Australia	3	1	0	Beef and bacon burgers	(*104*)
2009	Typhimurium	Australia	3	0	0	Pork mince	(*104*)
2009	Typhimurium	Australia	2	1	0	Chicken, eggs	(*104*)
2009	Typhimurium	Australia	2	1	0	Chicken	(*104*)
2009	Typhimurium	Australia	2	0	0	Eggs: tiramisu	(*104*)
2009	Typhimurium	France	8			Eggs, raw: tiramisu	(*80*)
2009	Typhimurium	Netherlands	23	8		Beef, raw or undercooked	(*138*)
2009	Typhimurium	New Zealand	19	5	0	Watermelon	(*91*)
2009	Typhimurium	US: CO	27	1	0	Lettuce, iceberg	(*33*)
2009	Typhimurium	US: MI	14	2	0	Sprouts, alfalfa	(*33*)
2009	Typhimurium	US: MO	6	1	0	Meat, head cheese	(*33*)
2009	Typhimurium	US: multistate	145	1		Lettuce, shredded	(*33*)
2009	Typhimurium	US: OH	2	1	0	Chicken	(*33*)
2009	Typhimurium	US: PA	5	3	0	Beef	(*33*)
2009	Typhimurium; Schwarzengrund	US: CT	9		0	Potato salad	(*89*)
2009	Virchow	Australia	10	3	0	Egg, pork roll	(*104*)
2009		US: FL	7	6	0	Fish, red snapper	(*33*)
2009		US: MN	19	0	0	Gravy	(*33*)
2008–2009	Rissen	US: 5 states	87	8	1	Pepper, white, ground	(*33*;*68*)
2008–2009	Typhi	Uganda	577	289	47	Water	(*99*)
2008–2009	Typhimurium	Australia	8	3	0	Egg-based sauces	(*108*)
2008–2009	Typhimurium	US: 46 states	714	166	9	Peanut butter	(*17*)
2007–2009	Java	Australia	75	3	0	Playground sand, contaminated by bandicoots	(*122*)
2008	Aberdeen	US: PR	4		0	Chicken; Plantains; Rice, yellow; Pigeon peas	(*33*)
2008	Anatum	Australia	11	0	0	Chicken	(*103*)
2008	Anatum	US: TN	50	2	0	BBQ, unspecified	(*33*)
2008	Barranquilla	US: MA	4	2	0	Fish: bass; Tuna, raw	(*33*)
2008	Barranquilla; Bovismorbificans; Braenderup; Javiana; Rubislaw; Thompson	US: VA	45	1	0	Fish: hybrid striped bass	(*33*)
2008	Berta	Italy	15			Eggs	(*50*)
2008	Blockley	US: CA	9	0	0	Molé; Pasta with tomato sauce	(*33*)
2008	Bovismorbificans	US: PA	8	2	0	Pasta salad	(*33*)
2008	Braenderup	Japan	176			Eggs: in boxed lunches	(*94*)
2008	Braenderup	US: CA	17	0	0	Peppers, jalapeno	(*33*)
2008	Braenderup	US: IA	12	5	0	Salad, green; Tomato, unspecified	(*33*)
2008	Braenderup	US: SC	27	1	0	Pork, BBQ	(*33*)
2008	Enteritidis	Austria	9			Eggs: in boxed lunches	(*96*)
2008	Enteritidis	Russia	39	30		Cakes	(*3*)
2008	Enteritidis	US: CA	15	3	0	Sauce, hollandaise	(*33*)
2008	Enteritidis	US: CA	4	2	0	Eggs: in raw cookie dough	(*33*)
2008	Enteritidis	US: CT	5	1	0	Chicken, buffalo wings	(*33*)
2008	Enteritidis	US: GA	11	1	0	Chicken fajita	(*33*)
2008	Enteritidis	US: KS	29	4	0	Guacamole; Salad	(*33*)
2008	Enteritidis	US: MA	18	10	0	Eggnog, homemade	(*33*)
2008	Enteritidis	US: MN	46	1	0	Turkey ham, sliced, deli	(*33*)
2008	Enteritidis	US: MN	15	0	0	Sandwich; Food worker	(*65*)
2008	Enteritidis	US: MN	7	3	0	Chicken, cordon bleu	(*33*)
2008	Enteritidis	US: NM	12	4	0		(*33*)
2008	Enteritidis	US: NY	66	16	0	Specialty/Ethnic dishes	(*33*)
2008	Enteritidis	US: NY	16	0	0	Beef, prime rib	(*33*)
2008	Enteritidis	US: NY	9	1	0	Aviyal (vegetable dish, Indian)	(*33*)
2008	Enteritidis	US: PA	15	1	0	Egg-containing food, other	(*33*)
2008	Enteritidis	US: PA	14	3	0	Unknown	(*33*)
2008	Enteritidis	US: SC	12	6	0	Macaroni and cheese (eggs)	(*33*)
2008	Enteritidis	US: VA	6	0	0	Eggs, scrambled	(*33*)
2008	Enteritidis	US: WA	82	4	0	Rice, fried, unspecified	(*33*)
2008	Hadar	US: IA	3	0	0	Turkey, sliced, deli meat	(*33*)
2008	Hadar	US: MN	6	3	0	Turkey, unspecified	(*33*)
2008	Hadar	US: NY	50	15	0	Turkey	(*33*)
2008	Hartford	US: multistate	22	0	0	Salsa, unspecified	(*33*)
2008	Heidelberg	US: CA	80	1	0	Taco, unspecified	(*33*)
2008	Heidelberg	US: CA	16	2	0	Macaroni and cheese	(*33*)
2008	Heidelberg	US: FL	5			Multiple foods	(*33*)

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Year	Serotype	Location	Cases	Hosp	Deaths	Vehicle	Reference(s)
2008	Heidelberg	US: IL	9	1	2	Pureed food diet	(*33*)
2008	Heidelberg	US: MN	2	0	0	Ice cream, homemade	(*33*)
2008	Heidelberg	US: VA	17	2	0	Eggs, omelette	(*33*)
2008	I 4,[5],12:i:-	US: MN	18	8	0	Chicken, stuffed	(*33*)
2008	I 4,[5],12:i:-	US: MO	43	3	0	Pudding, unspecified; Whipped cream, unpasteurized	(*33*)
2008	I 4,[5],12:i:-	US: NM	17	3	0	Guacamole, unspecified	(*33*)
2008	Infantis	US: PR	31	0	0	Pork	(*33*)
2008	Java	US: NJ	70	0	0	Cheese, cheddar	(*33*)
2008	Javiana	US: CA	594	31	0	Watermelon	(*33*)
2008	Javiana	US: multistate	10			Cantaloupe	(*33*)
2008	Javiana	US: NC	71	17	0	Pork, BBQ	(*33*)
2008	Johannesburg	Australia	14	1	0	Pork, roasted	(*103*)
2008	Montevideo	US: AZ	101	21	0	Chicken, raw; Cheese, unspecified; Cilantro	(*33*;*112*)
2008	Muenchen	US: OH	67	10	0	Beans, unspecified; Rice; Salsa, unspecified	(*33*)
2008	Muenster	France	25	4	0	Cheese, goat's, unpasteurized	(*131*)
2008	Muenster	US: PA	4	0	0	Pork, BBQ	(*33*)
2008	Newport	US: AR	4	1	0	Turkey, roasted	(*33*)
2008	Newport	US: AZ	87	7	0	Beef, tri-tip	(*33*)
2008	Newport	US: CO	3	1	0	Cantaloupe; Watermelon	(*33*)
2008	Newport; Reading	Finland	106	15	2	Lettuce, iceberg	(*81*)
2008	Panama	Netherlands	33	10		Juice, orange, unpasteurized, commercial	(*101*)
2008	Panama	US: NY	17	1	0	Fruit salad	(*33*)
2008	Rubislaw	US: TX	146	1	0	Meats	(*33*)
2008	Saintpaul	US: IA	3	0	0	Beef, ground	(*33*)
2008	Saintpaul	US: multistate	26	1	0	Turkey, ground	(*33*)
2008	Tennessee	Germany	18			Animal contact: bearded dragons	(*136*)
2008	Typhimurium	Australia	31	5	3	Vitamised foods	(*103*)
2008	Typhimurium	Australia	24	2	0	Eggs Benedict	(*52*;*103*)
2008	Typhimurium	Australia	24	1	0	Eggs: raw dressing	(*103*)
2008	Typhimurium	Australia	20	6	0	Eggs	(*103*)
2008	Typhimurium	Australia	18	1	0	Eggs: tiramisu	(*103*)
2008	Typhimurium	Australia	18	2	0	Chicken; Ham	(*103*)
2008	Typhimurium	Australia	16	0	0	Eggs: chocolate mousse	(*103*)
2008	Typhimurium	Australia	15	3	0	Bakery products	(*103*)
2008	Typhimurium	Australia	14	2	1	Vitaminised food	(*103*)
2008	Typhimurium	Australia	10	0	0	Eggs: chocolate mousse	(*103*;*115*)
2008	Typhimurium	Australia	10	1	0	Eggs: chocolate mousse	(*103*)
2008	Typhimurium	Australia	7	0	0	Beef chili	(*103*)
2008	Typhimurium	Australia	7	1	0	Eggs, raw, ice cream	(*103*)
2008	Typhimurium	Australia	4	1	0	Mixed dishes	(*103*)
2008	Typhimurium	Australia	4	3	0	Egg custard	(*103*)
2008	Typhimurium	Australia	4	1	0	Egg dessert	(*103*)
2008	Typhimurium	Australia	3	1	0	Egg, raw dressing	(*103*)
2008	Typhimurium	Australia	3	2	0	Eggs	(*103*)
2008	Typhimurium	Australia	3	0	0	Eggs, raw	(*103*)
2008	Typhimurium	Australia	3	3	0	Chicken	(*103*)
2008	Typhimurium	Australia	2	1	0	Sausage	(*103*)
2008	Typhimurium	Australia	2	0	0	Eggs, raw dressing	(*103*)
2008	Typhimurium	Netherlands	75	10		Unknown	(*51*)
2008	Typhimurium	Netherlands	18			Meat, butcher shop	(*51*)
2008	Typhimurium	Norway; Sweden; Denmark	51		4	Pork	(*14*)
2008	Typhimurium	Switzerland	205			Pork, other meat?	(*118*)
2008	Typhimurium	UK	179			Egg sandwiches, pre-packaged	(*13*)
2008	Typhimurium	US: 25 states	135	29	0	Animal contact: pet turtles	(*15*)
2008	Typhimurium	US: CA	24	1	0	Multiple Mexican foods	(*33*)
2008	Typhimurium	US: CA	6	2	0	Vegetable garnish	(*33*)
2008	Typhimurium	US: CA	5	2	0		(*33*)
2008	Typhimurium	US: CA	4	0	0	Chicken, roasted	(*33*)
2008	Typhimurium	US: multistate	24			Sprouts, alfalfa	(*33*)
2008	Typhimurium	US: NC	8			Chicken, unspecified	(*33*)
2008	Typhimurium	US: OH	5	0	0	Chicken, other	(*33*)
2008	Typhimurium var Cope	US: CA	4	0	0	Macaroni and cheese	(*33*)
2008	Virchow	Australia	3	0	0	Chicken curry	(*103*)
2008	Weltevreden	India	34			Fish	(*6*)

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Year	Serotype	Location	Cases	Hosp	Deaths	Vehicle	Reference(s)
2008		Estonia	80	3		Chicken	(*4*)
2008		US: CA	10	1	0	Chicken, BBQ	(*33*)
2008		US: FL	4			Spring rolls, unspecified	(*33*)
2007–2008	Montevideo	Japan	57			Fish, sushi	(*62*)
2007–2008	Senftenberg	Serbia	14	4		Tea, baby, with fennel seeds	(*71*)
2007	Cubana	Canada	20			Sprouts, onion	(*76*)
2007	Enteritidis	Bosnia & Herzegovina	695	201		Chicken; Mayonnaise; Infected worker	(*8*)
2007	Enteritidis	Denmark	10			Eggs, raw, in dessert	(*2*)
2007	Enteritidis	Singapore	216	18	0	Cream cakes	(*45*)
2007	Litchfield	US: NJ	30	6	0	Fruit, melon	(*16*)
2007	Montevideo	US: 20 states	65	8	0	Animal contact: chicks	(*66*)
2007	Montevideo	US: 23 states	64	8	0	Animal contact: chicks	(*66*)
2007	Newport	US: 4 states	42	17	0	Beef, ground	(*119*)
2007	Typhi	India	103	6		Water; Milk products; Food handler	(*9*)
2006–2007	Typhimurium	Netherlands	224	59		Cheese, hard, raw milk	(*132*)
2006	Tennessee	US: CO	12			Person to person in ICU	(*11*)

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Chronological List of *Salmonella* Outbreaks with a Certain or Probable Vehicle (2008–2013)

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APPENDIX:
Chronological List of *Salmonella* Outbreaks with a Certain or Probable Vehicle (2008–2013)

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