SURVEILLANCE OF INFECTIOUS DISEASES

IN ANIMALS AND HUMANS IN SWEDEN 2022

Chapter excerpt:
Salmonellosis

NATIONAL VETERINARY INSTITUTE

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Cover: A cultivation of *Salmonella* at the Public Health Agency of Sweden.
Photo: Nicklas Thegerström/DN/TT. Cover design by Rodrigo Ferrada Stoehrel.

Reporting guidelines: Reporting guidelines were introduced in 2018 for those chapters related to purely animal pathogens. The guidelines build on experiences from several EU projects, and have been validated by a team of international experts in animal health surveillance. The aim is to develop these guidelines further in collaboration within the global surveillance community and they have therefore been made available in the form of a wiki on the collaborative platform GitHub (https://github.com/SVA-SE/AHSURED/wiki). Feel free to contribute!

Layout: The production of this report continues to be accomplished using a primarily open-source toolset. The method allows the source text to be edited independently of the template for the layout which can be modified and reused for future reports. Specifically, the chapter texts, tables and captions are authored in Microsoft Word and then converted to the LaTeX typesetting language using a custom package written in the R software for statistical computing. The package uses the pandoc document conversion software with a filter written in the lua language. Most figures and maps are produced using R and the LaTeX library pgfplots. Development for 2022 has focused on generalising the R package to accommodate conversion into formats other than LaTeX and PDF, with a focus on markdown files which can be published as HTML websites using the Quarto publishing system. The report generation R package and process was designed by Thomas Rosendal, Wiktor Gustafsson and Stefan Widgren.

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Salmonellosis

BACKGROUND

Salmonellosis is one of the most important bacterial zoonoses. The genus is divided into two species: *S. enterica* and *S. bongori*. Most *Salmonella* belong to *S. enterica* subspecies *enterica*. More than 2500 different serovars belonging to this subspecies have been described. *Salmonella* can infect a multitude of animal species, including humans. Humans are infected by contaminated food products of various types, through contact with infected animals, via person-to-person transmission or via a contaminated environment.

A severe domestic outbreak of *S.* Typhimurium in 1953 with more than 9000 cases prompted the need for a control programme for *Salmonella* in Sweden. Since then, the strategy for control has been developed to prevent *Salmonella* in all parts of the production chain, from feed to food of animal origin. When Sweden joined the European Union in 1995, the Swedish *Salmonella* control programme was accepted. Sweden obtained additional guarantees for live animals, meat, and eggs from countries with a non-equivalent *Salmonella* status to be tested for the presence of *Salmonella* before entering the Swedish market. The control programme constitutes an important safeguard to Swedish public health. In 2021, the Swedish Board of Agriculture (SBA) and the National Veterinary Institute (SVA) received a joint government assignment to review the control programme and make suggestions for a revision taking into account the structural changes in primary production towards fewer and larger production sites. In spring 2022, the review of the programme was finalised and a control programme with strengthened biosecurity programmes and surveillance and a more risk-based management of infected herds was proposed. Preparatory work for the revision of the programme is ongoing.

In recent years, a total of 2000–3000 human cases of salmonellosis have been reported annually to the Public Health Agency of Sweden. A majority (60–80%) of these cases were infected abroad. During the last decade, the number of cases infected abroad has decreased, whereas the domestic incidence has remained stable. Still, the proportion of domestic infections in Sweden is low compared to many other countries. The source of the verified outbreaks is often imported food. The contribution from domestic food-producing animals to the human disease burden is low. In 2022, as in 2021, the COVID-19 pandemic resulted in both a very low incidence of salmonellosis and a very high proportion of domestic infections.

DISEASE

Animals

Infected animals are often asymptomatic. However, *Salmonella* can cause clinical illness with diarrhoea, abortions, and fever, and even lead to death. In Sweden, clinical signs are frequently seen in cattle, horses, cats and dogs, whereas infected poultry and pigs are most commonly asymptomatic.

Humans

Salmonella infects the gastrointestinal tract and causes an acute gastrointestinal illness. The symptoms can range from asymptomatic and mild to severe. The incubation period is typically between 1 and 3 days but can vary from 6 hours to 10 days. Most patients recover from the illness spontaneously but sequelae such as reactive arthritis occur in approximately 1–15% of the patients. Excretion of the pathogen normally lasts for four to six weeks but prolonged asymptomatic excretion can occur. In rare but severe cases the infection can spread via the bloodstream to organs outside the gastrointestinal tract.

LEGISLATION

Feed

Control of animal feed is an integrated and essential part of the control programme for *Salmonella* in primary production. Feed business operators are responsible for producing *Salmonella*-free feed. Poultry feed must be heat-treated according to legislation. A major part of cattle and pig commercial feed is also heat-treated. The production of feed is supervised by the SBA which carries out announced and unannounced inspections at feed mills and pet food producers. The control of *Salmonella* in feed is regulated in national legislation (SJVFS 2018:33 with amendments, SJVFS 2022:3) as well as in an EU regulation (Commission Regulation (EU) No142/2011).

Animals

Investigation is required upon clinical suspicion of salmonellosis and any finding of *Salmonella*, regardless of serovar, is notifiable. Action is taken to eliminate the infection or contamination except in cases of findings of *S. diarizonae* serovar 61:(k):1,5(7) in sheep. Vaccination is not used in Sweden. The *Salmonella* control programme is governed by the Swedish Act on Zoonoses (SFS 1999:658) and its regulations. The aim of the programme is that animals sent for slaughter and animal products should be free from *Salmonella*.

Food

Any finding of *Salmonella* in food is notifiable and a contaminated food product is considered unfit for human consumption. However, there is one exception, which is *S. diarizonae* serovar 61:(k):1,5(7) in sheep meat, as this serovar is not considered to be of public health importance (LIVFS 2005:20).

Laboratories analysing samples taken by authorities are obliged to send isolates of *Salmonella* from positive food samples to the National Reference Laboratory for serotyping (LIVFS 2005:21).

Humans

Salmonellosis in humans is notifiable according to the Communicable Disease Act (SFS 2004:168 with amendments,

SFS 2022:217). Laboratory confirmed cases include cases with samples that are positive by PCR only i.e., where no isolate has been obtained.

MEASURES IN CASE OF FINDINGS OF *SALMONELLA*

Isolates

All suspected isolates of *Salmonella* from non-human sources are sent to SVA for confirmation and serotyping. Index cases are defined as the first isolate of *Salmonella* in a holding with pigs, cattle, goats, sheep, horses or a poultry flock during the period of restriction measures. For companion animals, index cases are defined as the first isolate of *Salmonella* from a companion animal in a household or a kennel of a specific species during a calendar year. For wild animals, the index case is defined as the first isolate from a wild animal species in a municipality or a locality during a calendar year. Index isolates from index cases as well as other index isolates (new serovars from a holding, flock or companion animal in which another serovar has previously been detected, findings of *Salmonella* at postmortem or in a lymph node but not confirmed in a holding and *S. diarizonae* serovar 61:(k):1,5(7) in sheep) are resistance tested. From cats and passerine birds, however, a subset of isolates is resistance tested and further typed. In addition, one isolate per holding from holdings under restrictions are resistance tested each year. Isolates of *S.* Typhimurium are further typed by MLVA. From 2020 onwards a subset of isolates of all serovars from food and animal sources is characterised by whole genome sequencing (WGS).

All isolates of *Salmonella* from domestic human cases are sent to the Public Health Agency of Sweden for typing using WGS. A subset of isolates from travel-associated cases are also typed. Both serotype and resistance markers are identified from the sequence data. Clustering of isolates is also done to identify outbreaks and for source tracing.

Feed

Findings of *Salmonella* in intra-community traded or imported feed materials and compound feeds are reported in the Rapid Alert System for Food and Feed (RASFF) (https://ec.europa.eu/food/safety/rasff_en). Measures are always taken when *Salmonella* is detected in feed samples. *Salmonella*-positive feed materials are usually treated with organic acids. After acid treatment the feed material must be re-tested negative before use in feed production. Finished feed containing *Salmonella* must be withdrawn from the market. Extended sampling and cleaning are done in the production line if *Salmonella* is detected in the weekly surveillance. If *Salmonella* is found before heat treatment, the contaminated part of the production line is thoroughly cleaned and disinfected, usually by dry cleaning, followed by disinfection. If *Salmonella* is found after heat treatment, the production will be stopped, and the feed mill must be thoroughly cleaned and disinfected. Environmental sampling must show negative results before production is resumed.

Animals

If *Salmonella* is suspected in an animal, a veterinarian is obligated to take samples and implement measures to prevent further transmission. When *Salmonella* is detected, the laboratory must notify the SBA and the County Administrative Board. When detected in a food-producing animal, the County Veterinary Officer informs the official veterinarian at the abattoir involved.

When *Salmonella* is confirmed on a farm, the holding is put under restrictions (except in cases of finding of *S. diarizonae* serovar 61:(k):1,5(7) in sheep), an epidemiological investigation is performed and a plan to eradicate *Salmonella* from the holding is defined. Animal movements to and from the holding are stopped.

All *Salmonella*-positive poultry flocks are euthanised irrespective of serovar. The poultry house involved, and all possibly contaminated areas are thoroughly cleaned and disinfected. Before introduction of new birds, all environmental samples must be negative for *Salmonella*.

In pigs and cattle, a combination of partial herd depopulation and hygienic measures monitored by repeated sampling is usually practiced. Cattle herds under restrictions for *Salmonella* are monitored by a combination of serological and bacteriological testing. Hygienic measures can include reducing the number of animals, control of animal feed and manure management on the farm and reduction of *Salmonella* contamination in the environment by cleaning and disinfection. Animals from restricted herds may be slaughtered after sampling with negative results. The restrictions are lifted when the cleaning and disinfection have been completed and *Salmonella* cannot be detected by culture from whole-herd sampling at two occasions performed four weeks apart.

If *Salmonella* is detected in companion animals, advice on hygienic measures to prevent further spread to other animals or humans is given to the owners. If *Salmonella* is detected in horses, the stables and/or the paddocks at risk are put under restrictions and follow up investigations are performed on the premises.

Food

Products released on the market will be withdrawn and contaminated products will be destroyed or sent for special treatment to eliminate the *Salmonella* bacteria, except for *Salmonella diarizonae* serovar 61:(k):1,5(7) in sheep meat.

Findings in imported consignments are reported in the RASFF system and the consignments will be returned to the country of origin, destroyed, or sent for special treatment as applicable. RASFF is also used to inform about contaminated Swedish food products released on the EU market or within Sweden.

In food enterprises where *Salmonella* has been detected, appropriate follow-up measures will be applied, such as careful cleaning and disinfection and environmental sampling.

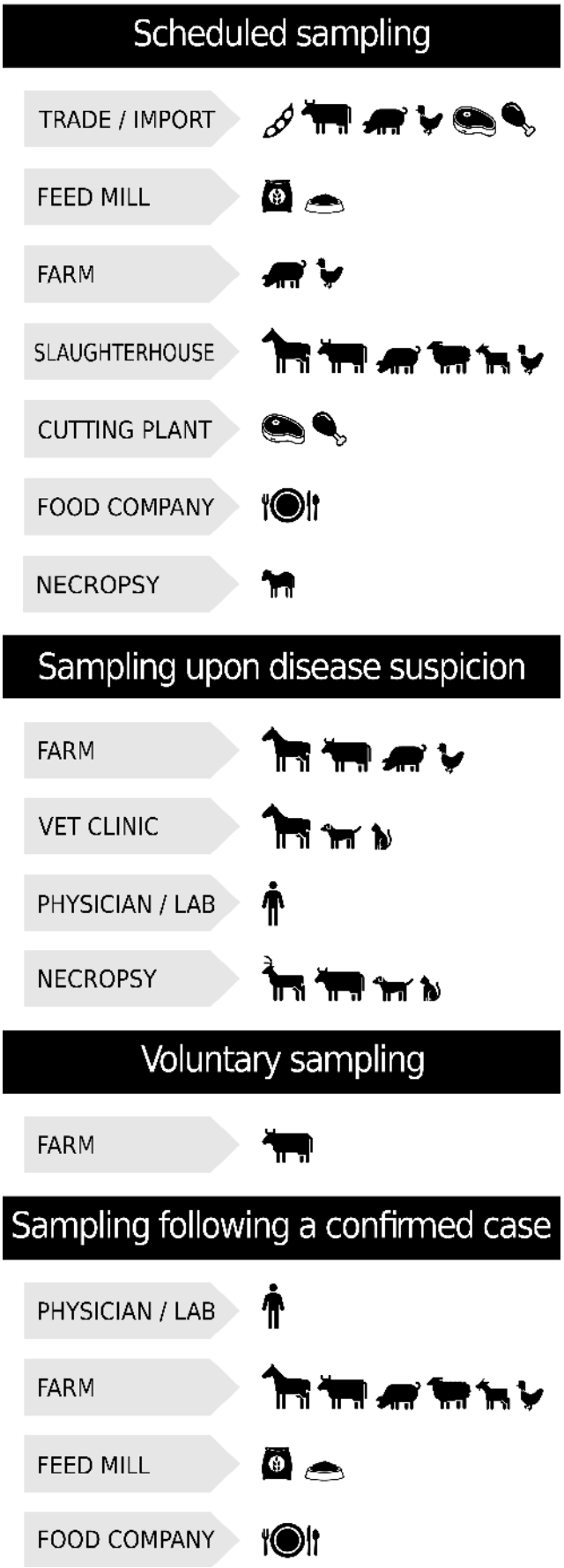

Figure 35: An illustration of the Swedish surveillance of *Salmonella* in feed, food, animals and humans. Infographic by Arianna Comin.

SURVEILLANCE

Feed

In the control programme for feed, the emphasis is on control of feed raw materials, the heat treatment process, and preventive measures to avoid recontamination of heat-treated feed. Suspected feed-borne infections are also investigated (Figure 35).

Surveillance of intra-community traded and imported compound feed and feed raw materials

Raw feed materials are the most important risk factor in feed production. In the domestic legislation, feed materials are classified according to the empirical risk of being contaminated, and high-risk feed materials must test negative for *Salmonella* contamination before being used in feed production. All consignments of intra-community traded or imported compound feed for cattle, pigs, poultry and reindeer and feed materials classified as a risk must be sampled and tested for *Salmonella*. The sampling plan is designed to detect a *Salmonella* contamination in 5% of the batch with 95% probability.

Surveillance of feed mills

The purpose of the surveillance is to ensure the absence of *Salmonella* in the production lines as well as in the feed mill environment. A safety management system is applied in the processing line according to HACCP (Hazard Analysis and Critical Control Points). The management system covers several specific GMP (Good Manufacturing Practices) requirements, according to the Swedish legislation. A minimum of five dust samples from feed mills that manufacture compound feedstuffs for poultry and a minimum of two dust samples from those manufacturing compound feedstuffs for other food-producing animals must be collected in the processing line on a weekly basis. These samples are analysed at SVA (using the latest version of EN-ISO 6579-1:2017, MSRV) and any finding of *Salmonella* is reported to the SBA. The feed manufacturers also take additional samples from the processing line and the feed mill environment as part of their own process quality control.

Pet food and dog chews

Sampling is performed by the feed business operators as part of their feed safety management system. Consignments of pet food and dog chews imported from third countries are sampled according to a sampling plan at the border inspection. The sampling plan is defined based on a risk assessment.

Animals

In all animal samples except for those taken within the control programme at abattoirs, detection of *Salmonella* is performed using the latest version of the EN-ISO 6579:2017-1 method or a method validated against it. Measurement of antibodies against *Salmonella* in blood or milk samples of cattle is performed using commercial ELISA tests PrioCHECK® Salmonella Ab bovine ELISA and PrioCHECK® Salmonella Ab bovine Dublin (Thermo Fisher Scientific, Lelystad, Netherlands).

Poultry

The programme comprises a compulsory part and a voluntary part. The purpose of the compulsory programme is to ensure that poultry sent for slaughter and meat products are free from *Salmonella*. All poultry species are included in the compulsory part, which sets the rules for mandatory sampling (Figure 35).

Compulsory programme

All breeding flocks with more than 250 birds are tested (Table 17). Grandparents of *Gallus gallus* broilers are imported as day-old chicks. Laying hens, turkeys, geese, and ducks are imported as parents. Samples consist of sock samples (free range systems) or faecal samples (cage systems) taken from all parts of the building or the department where the bird flock is kept. From rearing flocks, two pairs of sock samples are taken and pooled into one whereas five pairs pooled into two are taken from the breeding flocks in production.

All holdings that sell eggs for consumption are sampled (Table 17), except those with fewer than 200 birds that only sell directly to consumers. All poultry flocks that have more than 500 birds, irrespective of species, must be tested. In practice, all poultry flocks are tested prior to slaughter and the results must be available before slaughter. According to the harmonised legislation, sampling needs to be performed within 3 weeks prior to slaughter.

The poultry producers pay the costs for the laboratory analyses and the visits to the farms. Only accredited laboratories are allowed to perform the analyses. County Veterinary Officers supervise the poultry control programme regionally. The laboratory sends the test results to the County Veterinary Officer on a quarterly basis. According to regulations, the County Veterinary Officer must send a report on the test results of all poultry holdings to the SBA once a year.

Voluntary programme

The aims of the voluntary programmes are to prevent introduction of *Salmonella* into poultry holdings and minimise the risk of spread of the infection to animals and humans. The voluntary programmes have been in place for more than 40 years.

All broiler and turkey producers belonging to the Swedish Poultry Meat Association are affiliated with the voluntary programme which represents approximately 99% of slaughtered broilers and 91% of turkeys. This voluntary preventive programme includes hygiene and biosecurity measures and a high standard for poultry house construction, such as biosecurity barriers between the clean and unclean parts. Purchases of animals may only occur from holdings affiliated with the voluntary programme and only heat-treated feed is allowed. The poultry houses must be cleaned and disinfected before introduction of a new flock. The poultry producer needs to make an application to be accepted into the voluntary programme and a veterinarian inspects the holding at least once a year.

The Swedish Egg Association is responsible for the voluntary programme of the egg line (laying hens, pullets, breeders). The voluntary programme of the egg line resembles that of the meat line. However, a voluntary programme is also available for holdings with outdoor access. Producers affiliated with the voluntary programmes of the egg line receive higher financial compensation in case of a finding of *Salmonella*.

Cattle and pig herds

This programme includes a compulsory and a voluntary component (Figure 35).

Compulsory programme

The aim of the programme is to ensure a low prevalence of *Salmonella* in cattle and pig herds. In pigs, the compulsory part consists of annual faecal sampling in nucleus and gilt-multiplying herds and biannual sampling in the central units of sow pools (multisite production system). In cattle, *Salmonella* testing is performed in all calves <15 months of age that are submitted for necropsy. In both cattle and pigs, testing is also performed in conjunction with necropsies if *Salmonella* infection is suspected based on macroscopic findings. All imported animals are also tested and, on clinical suspicion, any herd or single animal should be tested for *Salmonella*.

Voluntary programme

The voluntary programme is a general preventive biosecurity programme ("Smittsäkrad besättning") aiming at decreasing the risk of introduction of *Salmonella* and other infections. Holdings affiliated with the programme receive

Table 17: Sampling scheme for *Salmonella* in poultry.

Category of poultry	Sampling frequency	Sample type	Sampling before slaughter	Official veterinarian
Breeders in rearing	1 d, 4 weeks, 2 weeks prior to rearing or moving	2 pairs of sock samples	Within 3 weeks before slaughter	Once a year
Breeders in production	every 2nd week	5 pairs of sock samples	Within 3 weeks before slaughter	3 times during production
Layers in rearing	2 weeks prior to moving	2 pairs of sock samples or 2 faecal samples of 75 g	Within 3 weeks before slaughter	Once a year
Layers in production	every 15th week (start at 22–26 weeks)	2 pairs of sock samples or 2 faecal samples of 75 g	Within 3 weeks before slaughter	Once a year
Poultry for meat production (all species)		2 pairs of sock samples or 2 faecal samples of 75 g	Within 3 weeks before slaughter	Once a year

higher compensation in case of positive findings. In addition, affiliated holdings are entitled to apply for a commercial *Salmonella* insurance. Most sow breeding herds and many of the large dairy herds are affiliated with this programme.

In addition, there is the FriskKo ("Healthy Cow") programme which includes testing for *Salmonella* antibodies in bulk milk samples collected four times a year. All herds with test-positive results in this programme are offered veterinary consultations aimed at improving internal biosecurity to control and eradicate any *Salmonella* infection from the herd.

Serological screening of salmonella in dairy herds

In 2022, regional bulk milk screenings were performed on the islands of Gotland and Öland in April and October. Gotland and Öland were the counties with the highest proportion of test positive herds in the national screening in 2019. All samples were analysed with PrioCHECK® Salmonella Ab bovine ELISA (O antigens 1, 4, 5, 12 and 1, 9, 12; Thermo Fisher Scientific, Lelystad, Netherlands). Samples with a PP-value higher than twenty (PP>20) in this first test were also analysed with PrioCHECK® Salmonella Ab bovine Dublin ELISA (Thermo Fisher Scientific, Lelystad, Netherlands; JV Dnr 6.2.18-14893/2019).

Serological screening of salmonella in pig herds

During spring 2022, a serological screening in pig herds was performed as part of the ongoing revision of the control programme. Sows in herds with >120 sows that were affiliated with the voluntary biosecurity programme were sampled with the aim to evaluate serology as a tool for the control programme in pigs, estimate prevalence in piglet-producing and integrated herds and to use the results to design a serological surveillance component for pigs sampled at abattoirs. Samples were analysed using IDEXX Swine Salmonella Ab Test (IDEXX, Hoofddorp, The Netherlands).

Other animals

Animals are tested for *Salmonella* on clinical suspicion or as part of trace-back investigations (Figure 35). Wild animals necropsied at SVA are also tested for *Salmonella* on suspicion (see chapter "Post mortem examinations in wildlife" on page 151).

Surveillance of *Salmonella* in wild boar was initiated during 2020 following the detection of *Salmonella* Choleraesuis in a breeding herd of domestic pigs. This serovar had been absent from domestic pigs in Sweden for a period of more than 40 years. Samples from wild boars found dead and reported to SVA and a subset of apparently healthy shot wild boars were analysed for *Salmonella* according to ISO 6579:1. Suspected isolates of *S.* Choleraesuis were whole genome sequenced for confirmation and further typing. With the purpose of detecting disease presence in new areas and monitoring of the situation, this surveillance activity is ongoing.

Food

Control of *Salmonella* is an important part of in-house quality control programmes in many food enterprises in Sweden (Figure 35). All findings must be reported to the competent authority.

Between 500 and 1000 samples per year are tested as part of official sampling by local or national authorities at food enterprises, in addition to the sampling performed at slaughterhouses and cutting plants. These samples are mainly analysed using a method validated against the reference method EN ISO 6579-1 or NMKL (nr 71:1999).

Isolates of *Salmonella* from samples of food taken by authorities are always sent for serotyping at the National Reference Laboratory for *Salmonella* (see Legislation). Although there are no legal requirements, laboratories most often also send isolates from samples taken by food business operators for confirmation. Serotyping and in some cases whole genome sequencing of these isolates is funded by the SBA, provided that the food business operator agrees that the results are made available to the national authorities. Data from 2007 and onwards are stored in a database at SVA.

Surveillance at slaughterhouses and cutting plants

According to the Swedish *Salmonella* control programme, samples from intestinal lymph nodes and swabs from carcasses are taken from cattle and pigs while neck skin samples are taken from slaughtered poultry. The sampling frame includes all slaughterhouses that slaughter more than 50 tons per year. These plants are responsible for more than 99% of the slaughter of cattle, pigs and poultry in Sweden. Sampling at each slaughterhouse is proportional to the annual slaughter volume. The total number of samples taken is calculated to detect a prevalence of 0.1% with 95% confidence level in cattle, pig, and poultry carcasses at a national level. Altogether, approximately 21 000 samples from cattle, adult pigs, fattening pigs, and poultry are collected at slaughterhouses annually.

At red meat cutting plants, approximately 5000 samples are taken annually from meat residues. Similarly, approximately 1000 samples are taken in poultry meat cutting plants.

The samples are analysed by commercial laboratories using the current edition of the NMKL (nr 71:1999) method. Up to 10 samples may be pooled into a single sample. If *Salmonella* is detected in a pool of lymph nodes, the samples included are analysed separately.

Food business operators are obliged to take swab samples from carcasses of sheep, goats, and horses at slaughterhouses for *Salmonella* analysis according to the regulation (EG) 2073/2005 on microbiological criteria for foodstuffs. The results of these analyses are to be reported to EFSA, but they are not yet collected by the competent authority. In Sweden, the corresponding requirements for swab sampling of carcasses of cattle and pigs and sampling of neck skins of poultry carcasses are replaced by the sampling within the *Salmonella* control programme.

IN FOCUS: *Salmonella* Enteritidis outbreak associated with domestic table eggs

Salmonella Enteritidis is the most common cause of food-borne human salmonellosis in Europe. The infection is most often acquired through the consumption of contaminated poultry products, with eggs from infected laying hens being the primary source. Not only can *S.* Enteritidis contaminate the outer eggshell, but the contents of the eggs from infected hens may also be contaminated. In Sweden, findings of *S.* Enteritidis in poultry have been uncommon and, prior to 2022, the serovar had been detected in commercial laying hens only 3 times since 2003.

In late December 2022, *S.* Enteritidis was detected in laying hens at Sweden's largest egg producing facility. The pathogen was first identified in a routine environmental sample taken in the facility's on-site egg packing plant. After subsequent environmental sampling of all barns at the facility, *S.* Enteritidis was identified from two departments in one barn. The facility was placed under restrictions and the infected flocks were euthanised. Eggs produced at the facility from the end of November and forward that had already reached market were recalled at the beginning of January 2023. Later, in February 2023, *S.* Enteritidis was detected in samples from three additional barns. Until negative sampling results are obtained, eggs produced after findings of *S.* Enteritidis are either sent for destruction or to a designated establishment for heat treatment.

Whole genome sequencing has linked 81 human cases to the strain recovered from the facility. The source of the outbreak in the laying flock has yet to be identified. However, isolates from the outbreak are genetically similar to isolates from other European outbreaks caused by eggs contaminated with *S.* Enteritidis. Notably, Belgium experienced a large nationwide outbreak with an almost identical strain (<5 SNP difference) during the first quarter of 2022 that could be linked to domestic eggs from one producer. Similar strains have also appeared in a couple of long-lasting outbreaks with cases in multiple countries linked to Polish (2014–2019) and Spanish (2018–2021) eggs (ECDC and EFSA 2020; ECDC and EFSA 2022). In addition, the outbreak strain is similar (14 SNP difference) to a smaller Danish egg-linked outbreak in early summer 2022. This raises questions about a possible common source of infection, but such a connection has not yet been identified. One explanation, however, could be that the strain enters production facilities in different countries by being present in the highly centralised breeding pyramid (Li et al., 2021). Findings of a different strain of *S.* Enteritidis at a smaller Swedish egg producer in September 2022 lends support to this hypothesis as a strain similar to this (13 SNP difference) was also causing a third large European egg-related outbreak in 2015–2017 (ECDC and EFSA 2017; Pijnacker et al., 2019).

Humans

Surveillance in humans is based on identification of the disease by a treating physician and/or by laboratory diagnosis (i.e., passive surveillance) (Figure 35). Both treating physicians and laboratories are obligated to report cases of salmonellosis to the regional and national level to enable further analyses and adequate intervention measures. *Salmonella* spp. is part of the microbial surveillance programme at the Public Health Agency of Sweden and domestic isolates are whole genome sequenced for serovar determination, assessment of diversity and cluster detection. The long-term goal is to use the data to evaluate efforts to lower the level of domestic incidence of *Salmonella* infection.

RESULTS

Feed

Fifteen major feed mills produce approximately 95% of the feed for food-producing animals. In the weekly surveillance of feed mills, 8611 samples were analysed for *Salmonella;* 42 of these samples (0.49 %) were positive. Thirteen serovars were detected; *S.* Typhimurium and *S.* Mbandaka were the most common (n=10) (Table 18).

In addition, *Salmonella* was detected in 20 out of 1887 analysed batches from feed materials of vegetable origin. The most common serovar was *S.* Tennessee (n=7). No *Salmonella* was detected during the year in feed materials of animal origin or from pet food out of 1194 analysed batches.

Animals

Poultry

Salmonella was detected in nine of 4047 broiler flocks tested (Table 19 and Figure 36). Six of these broiler flocks were found positive for *S.* Typhimurium through contact tracing after the parent flock that produced the eggs from which the broiler flocks hatched was suspected to be Salmonella-infected. *Salmonella* was detected in four of the 872 layer flocks tested (Figure 37). Two of these flocks, which tested positive for *S.* Enteritidis, belonged to Sweden's largest egg producer and were the source of a food-borne *Salmonella* outbreak (see "In focus"). *S.* Enteritidis of an unrelated genotype was detected in one other layer flock.

Table 18: Serovars of *Salmonella* isolated in feed control in 2022.

Serotype	Feed material of animal origin[A]	Pet food	Feed material of oil seed origin[B]	Feed material of cereal grain origin	Other plants[C]	Process control feed mills	Process control rapeseed crushing plant
S. Agona	-	-	1	-	-	5	-
S. Altona	-	-	-	-	-	1	-
S. Choleraesuis	-	-	1	-	-	-	-
S. Derby	-	-	1	-	-	-	-
S. enterica subspecies diarizonae (IIIb)	-	-	-	-	-	1	-
S. enterica subspecies enterica	-	-	-	1	-	-	-
S. enterica subspecies salamae (II)	-	-	-	-	-	1	-
S. Enteritidis	-	-	-	-	-	1	-
S. Havana	-	-	-	-	-	3	-
S. Isangi	-	-	-	-	-	6	-
S. Kingston	-	-	2	-	-	-	-
S. Mbandaka	-	-	-	-	-	10	-
S. Miami	-	-	-	-	-	1	-
S. Napoli	-	-	-	-	-	1	-
S. Ohio	-	-	-	1	-	1	-
S. Senftenberg	-	-	5	-	-	-	-
S. Tennessee	-	-	7	-	-	1	-
S. Typhimurium	-	-	-	-	-	10	-
Unknown	-	-	1	-	-	-	-
Total	**0**	**0**	**18**	**2**	**0**	**42**	**0**
Number of samples	1064	130	1242	645	144	8611	855

[A]Meat and bone meal, animal fat, fish meal, greaves, protein meal, meat meal, poultry offal meal, hydrolysed animal protein and animal by-products.
[B]Derived from palm kernel, rapeseed, soya bean, linseed, peanut and sunflower seed.
[C]Peas, beans, potatoes and hemp.

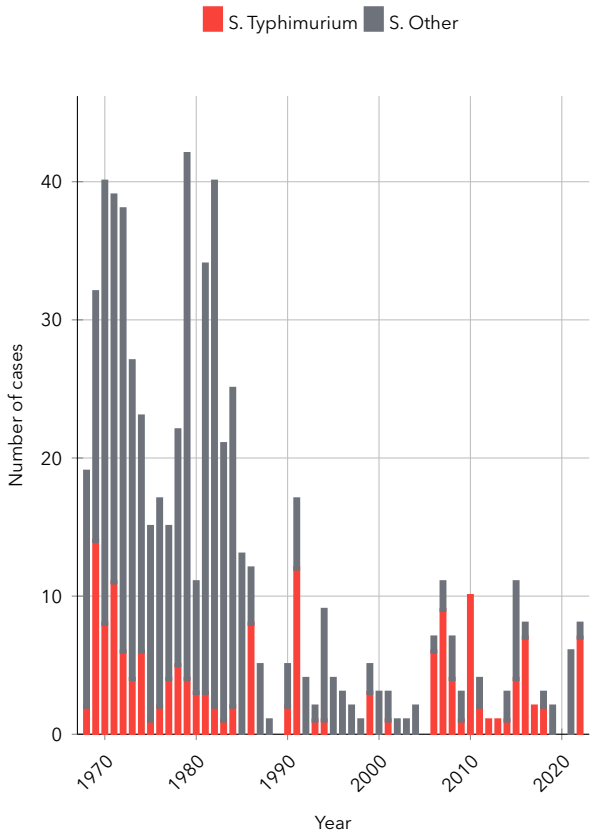

Figure 36: Annual notifications of *Salmonella* in broiler holdings from 1968–2022, breeding flocks included.

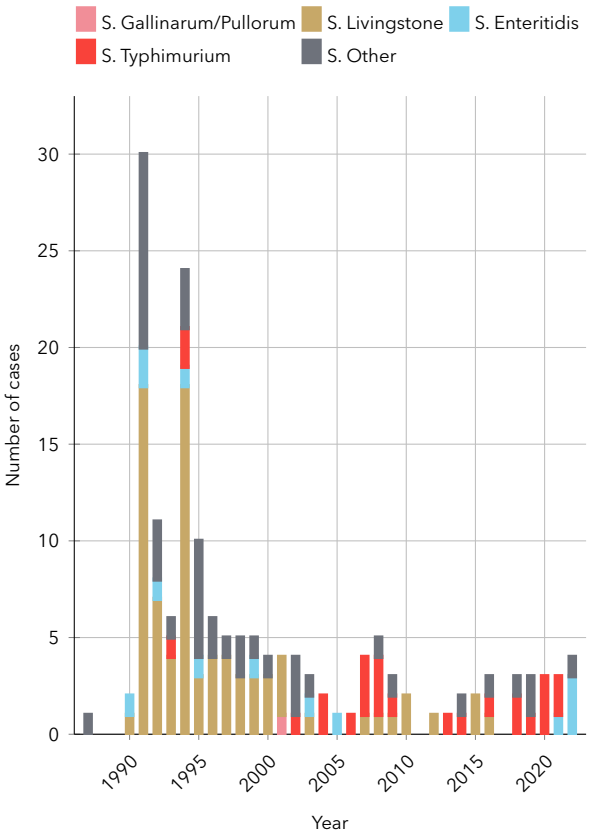

Figure 37: Annual notifications of *Salmonella* in layer holdings from 1987–2022.

Table 19: Results from the *Salmonella* control programme in commercial poultry flocks in 2022. The numbers of flocks tested are estimates due to deficiencies in the Swedish poultry registries and the lack of a unique flock identification.

Animal species	Production type	Production stage	No. flocks tested	No. positive	Percentage	Serovar
Gallus gallus	Meat production	Adult Grandparent	17	0	0.00%	-
Gallus gallus	Meat production	Adult Parent	124	0	0.00%	-
Gallus gallus	Meat production	Production	4047	9	0.22%	*S.* Typhimurium (n=8), *S.* Virchow (n=1)
Gallus gallus	Egg production	Adult Parent	14	0	0.00%	-
Gallus gallus	Egg production	Production	872	4	0.46%	*S.* Enteritidis (n=3), *S.* Infantis (n=1)
Turkeys	Meat production	Adult Parent	4	0	0.00%	-
Turkeys	Meat production	Production	166	0	0.00%	-
Geese	Meat production	Production	13	0		-
Ducks	Meat production	Production	23	0	0.00%	-

Salmonella was detected in one flock of quail. No flocks of commercially raised turkeys, ducks, geese, or ostriches tested positive for *Salmonella* in 2022. As the poultry registries maintained by the SBA are not sufficiently updated and a unique flock identification is lacking, the figures on the number of flocks within the programme and the number of flocks not sufficiently sampled, can only be considered estimates. It is estimated that approximately 20% of the poultry holdings lack an annual official sampling.

Cattle

In total, *Salmonella* was detected in four new herds in 2022 (Figure 38). *Salmonella* was isolated from six (0.15%) of 3940 mesenteric lymph nodes from cattle at slaughter (Table 20 and Figure 40). Two very large cattle herds which were placed under restriction due to *Salmonella* infections in 2020 remained under restriction throughout 2022. One herd is a dairy herd with *S.* Derby while the other is a specialised beef producing herd with *S.* Dublin. In both cases, the large size of the herds has made the control and eradication of *Salmonella* extremely difficult and costly and highlights the challenges that the current *Salmonella* control programme faces as cattle herds become bigger and more specialised.

In the regional bulk milk screenings on Gotland, 2.6% of the tested herds were positive in April (3/117) and 20% in October (24/120), of which none were positive in the Dublin ELISA. On Öland there were 15% (16/105) and 23% (27/117) test positive herds in April and October respectively, of which most were positive also in the Dublin ELISA. The results from October 2022 were at the same level as in October 2019 and this confirms a continued endemic situation of *Salmonella* Dublin on Öland. Regional screenings will continue to be performed in the following

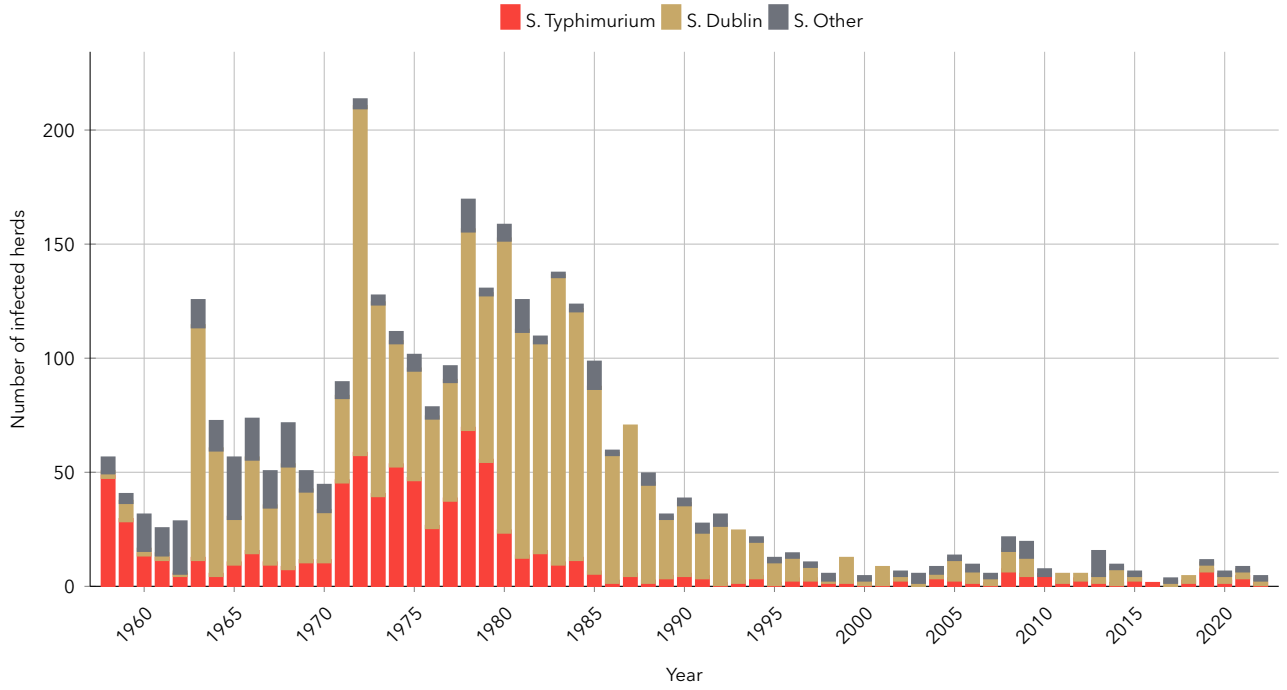

Figure 38: Annual notifications of *Salmonella* in Swedish cattle herds from 1958–2022. Data from 1958 through 1967 is extracted from a graph presented by J.Å. Robertsson (1985).

years to better understand variations between years and seasons and to follow the effect of a biosecurity programme targeted on salmonella positive herds.

Pigs

Salmonella was detected in two pig herds (Figure 39) and in three (0.09%) of 3522 lymph node samples taken from adult pigs and from two (0.06%) of 3429 lymph node samples from fattening pigs (Table 20, Figures 41 and 42).

It was estimated from the results of the serological investigation in piglet-producing and integrated pig herds that 11% (8–14%) of the herds were serologically positive for salmonella. The ELISA used cannot distinguish between serotypes and therefore no conclusions can be drawn concerning common serotypes or geographical clustering of serotypes.

Other animals

No horses tested positive for *Salmonella* in 2022. Index cases of *Salmonella* infection were detected in 941 cats, 8 dogs, 22 wild birds, 1 hedgehog and 1 roe deer (Table 21).

Salmonella was detected in 51 wild boars from 17 municipalities in five counties (Blekinge, Skåne, Stockholm, Södermanland and Östergötland; Table 22) In total during 2022, 200 wild boars were sampled and *S.* Choleraesuis was detected in 32 out of 83 wild boars found dead and in 14 out of 117 shot wild boars. In addition, other serovars were found in four wild boars found dead and in one shot wild boar. Serotypes other than *S.* Choleraesuis isolated from wild boar were *S.* Diarizonae (1), *S.* Typhimurium (1), *S.* Mapo (1) and one isolate belonging to the O7-group and one to the O4-group with no further typing available.

Food

Within the Swedish *Salmonella* control programme, swab samples were taken from 6740 pig carcasses and 3996 cattle carcasses. Neck skin samples were taken from 3062 poultry carcasses. *Salmonella* was not detected in any swab sample or neck skin sample (Table 20). At cutting plants, *Salmonella* was not detected in any of the 5419 red meat samples but in one of the 1319 poultry meat samples taken. (Table 20).

In addition to the sampling performed within the control programme, 534 samples were taken by national and local authorities at different food enterprises. *Salmonella* was detected in 16 samples, all from products originating from other countries than Sweden. (Table 23).

Table 20: Results from the *Salmonella* control programme at slaughterhouses and cutting plants in 2022.

Animal species	Sample type	No. samples	No. positive	Percentage	Serovar
Cattle	Lymph node	3940	6	0.15%	*S.* Choleraesuis (n=1), Monophasic *S.* Typhimurium (n=1), *S.* Coeln (n=1) *S.* enterica ss diarizonae (IIIb) 38;r;z (n=1), *S.* Enteritidis (n=1), *S.* Dublin (n=2)[A]
	Carcass swab	3996	0	0.00%	
Adult pigs	Lymph node	3522	3	0.09%	*S.* Choleraesuis, *S.* Typhimurium, *S.* enterica ss enterica (I) 6,8:eh:-)
	Carcass swab	3374	0	0.00%	
Fattening pigs	Lymph node	3429	2	0.06%	*S.* Typhimurium (n=2)
	Carcass swab	3366	0	0.00%	-
Cattle and pigs	Meat trimmings	5419	0	0.00%	-
Poultry	Neck skin	2940	0	0.00%	-
	Meat trimmings	1319	1	0.08%	*S.* Typhimurium

[A]In one sample of lymph nodes two serovars, *S.* Choleraesuis and *S.* Enteritidis, were detected.

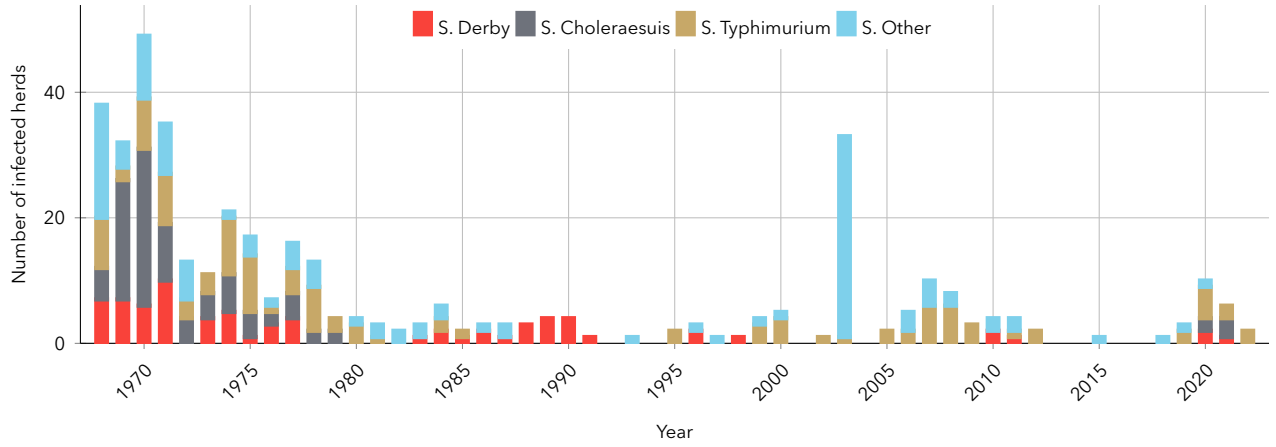

Figure 39: Annual notifications of *Salmonella* in pig herds 1968–2022. In 2003, a feed-borne outbreak of *S.* Cubana occurred in Sweden.

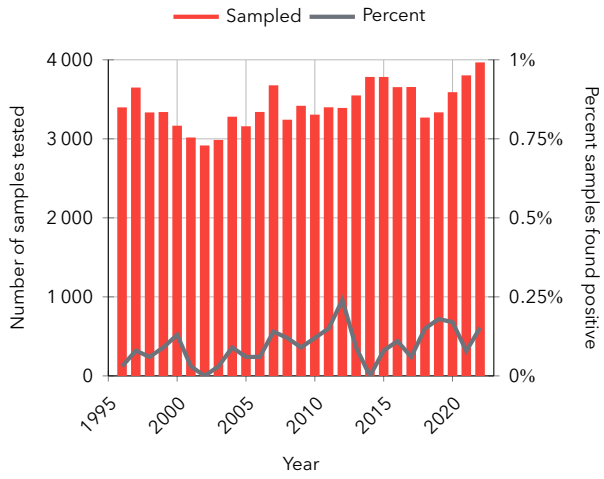

Figure 40: Samples tested (bars – left axis) and percentage of *Salmonella* found (line – right axis) in lymph node samples from **cattle** sampled at slaughterhouses.

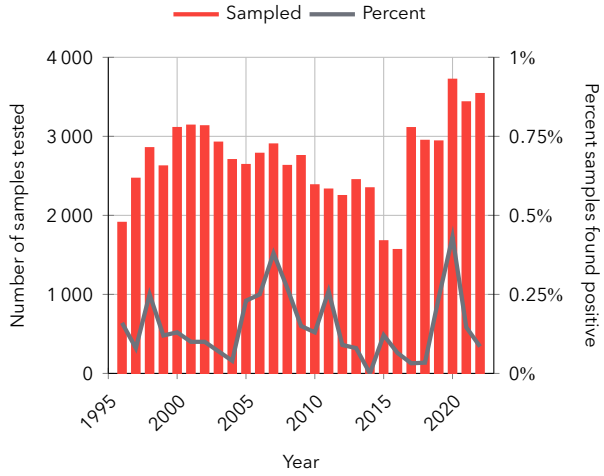

Figure 41: Samples tested (bars – left axis) and percentage of *Salmonella* found (line – right axis) in lymph node samples from **sows and boars** sampled at slaughterhouses.

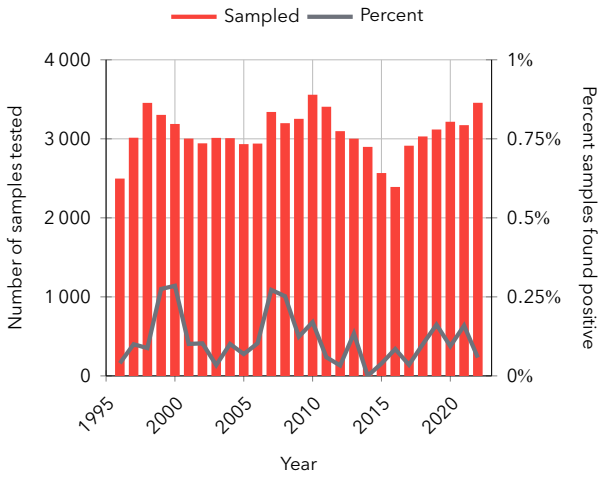

Figure 42: Samples tested (bars – left axis) and percentage of *Salmonella* found (line – right axis) in lymph node samples from **fattening pigs** sampled at slaughterhouses.

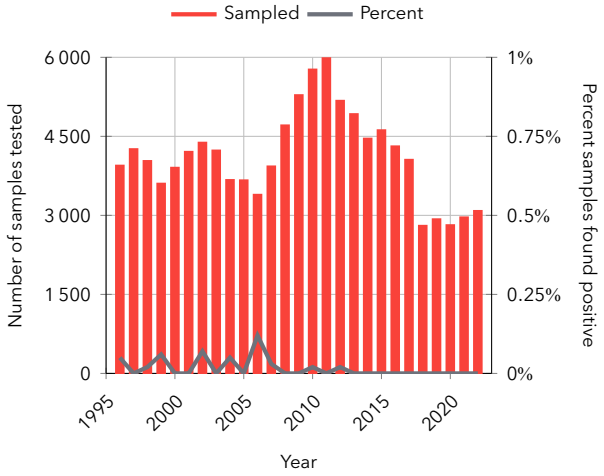

Figure 43: Samples tested (bars – left axis) and percentage of *Salmonella* found (line – right axis) in neck skin samples from **poultry** sampled at slaughterhouses.

Table 21: Notified index isolates of *Salmonella* in cats, dogs, horses, wild birds and wild mammals, except wild boar, in 2022. For all animal species, the number of index cases is the same as the number of index isolates.

Serovar	Cats	Dogs	Horses	Wild birds	Other wild animals
S. Agona	0	1	0	0	0
S. Enteritidis	1	0	0	0	1[A]
S. Fulica	0	0	0	2	0
S. Ndolo	1	0	0	0	0
S. Typhimurium	141	6	0	7	1[B]
Salmonella, 6,7:-:H5	0	1	0	0	0
Salmonella, O:4	798	0	0	13	0
Total index isolates	**941**	**8**	**0**	**22**	**2**
Total number tested[C]	1621	114	27	49	17

[A]Hedgehog
[B]Roe deer
[C]Total number of unique households (pets), stables (horses) or municipalities or locations (wild animals) tested.

Table 22: Results of surveillance of *Salmonella* in wild boar found dead, and in apparently healthy hunted wild boar during 2022.

County/Area	Category	Number sampled	*S.* Choleraesuis	Other *Salmonella*
Stockholm, Södermanland and Östergötland	Hunted	66	13 (20%)	1[A]
	Found dead	43	20 (46%)	1[A]
Skåne and Blekinge	Hunted	13	1[A]	0
	Found dead	24	12 (50%)	3 (13%)
Other counties	Hunted	38	0	0
	Found dead	16	0	0

[A]Percentage is not reported when the number of animals is low.

Sweden notified findings of *Salmonella* in food in the Rapid Alert System for Food and Feed (RASFF) at five occasions during 2022. All these concerned contaminated batches from other countries than Sweden, either intra-community traded or imported from third countries, within the food categories meat, poultry, fruit and vegetables, nuts and seeds and crustaceans.

In total, data from serotyped isolates from 652 batches of food or carcasses sampled at retail, slaughterhouses, or other food enterprises between 2010 and 2022 are available. Of these, 383 are from imported food batches, 183 of domestic origin (45 food batches and 138 carcasses) and 86 from food batches of mixed or unknown origin. The distribution of serovars differs between the major food categories (Figure 44). *S.* Dublin is the most common serovar in beef meat whereas *S.* Typhimurium and *S.* Derby are most common in pork meat. The composition of serovars from poultry meat is quite variable, but *S.* Newport and *S.* Infantis are the most common. Isolates from lamb meat (mainly originating from swab samples of carcasses) are almost exclusively *S. diarizonae* serovar 61:(k):1,5(7), whereas the composition of isolates from vegetables varies.

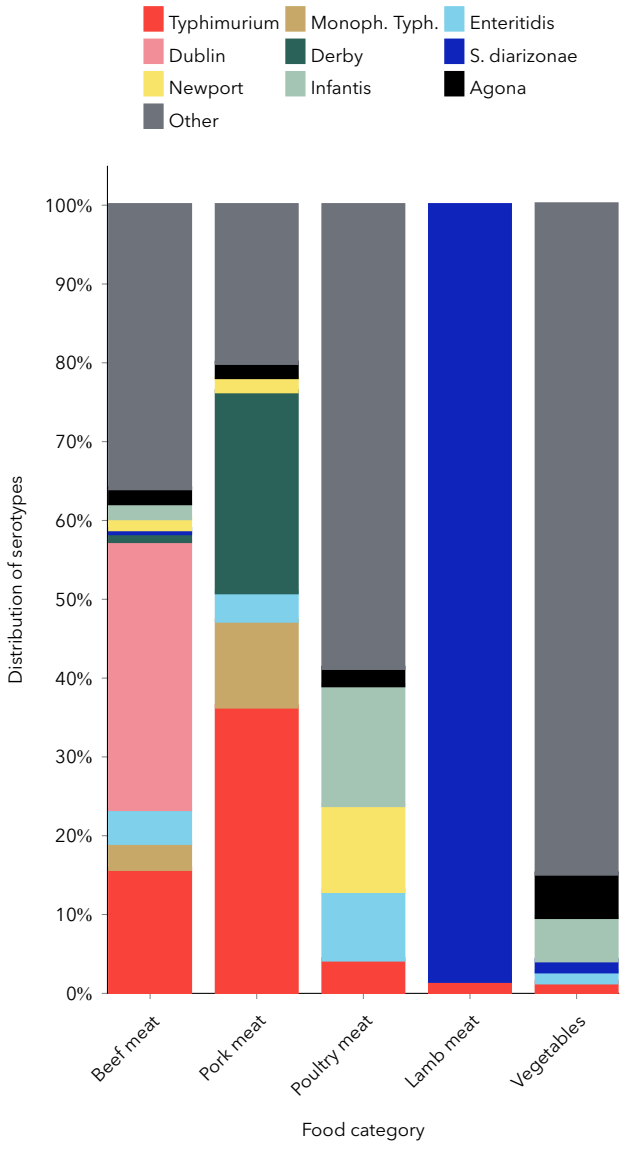

Figure 44: Distribution of *Salmonella* serovars in different food categories. Results of serotyping of isolates from samples taken at retail, slaughterhouses or other food enterprises by authorities or food business operators 2010 – 2022. In total, samples are from 483 batches of food or carcasses (beef meat 199, pork meat 54, poultry meat 42, lamb meat 124, vegetables 64). Food categories with isolates from samples of less than 20 batches are not included.

Humans

In 2022, a total of 1137 cases of salmonellosis were reported, compared to 944 cases in 2021 and 826 cases in 2020 (Figure 45). Domestic cases decreased from 721 cases in 2021 to 665 cases in 2022, resulting in an incidence of 6.3 cases per 100 000 inhabitants. The domestic incidence varies slightly from year to year but has been largely stable between 5 and 11 cases per 100 000 inhabitants over a long period with the exception for a drop to 4.1 in the first year of the COVID-19 pandemic.

A total of 39% of the cases (n=446) were considered to have been infected abroad. Since the turn of the millennium, a nearly fourfold decrease in incidence per 100 000 inhabitants among travel-associated cases had been observed until 2019, despite an increase in international travel. Reduced travel during the pandemic has led to the incidence of travel-related cases falling further to a minimum in 2021 of 1.8 cases per 100 000 inhabitants. In 2022, this number increased to 4.2 and Turkey was most often reported as the country of infection (n=96), followed by Spain (n=38) and Thailand (n=33).

Table 23: Results of *Salmonella* analyses of food samples taken by the authorities in 2022.

Reason for sampling	Total no. of samples	No. of positive samples
Survey	28	
Routine control	72	1 crayfish
Suspected food poisoning or complaint	309	3 minced meat, 1 chicken meat
Border control	102	4 sesame seed, 7 crayfish
Other or not reported	23	

Figure 45: Incidence (per 100 000) of notified human cases of salmonellosis in Sweden, 1997–2022. Travel-associated cases are those where the patient has reported travel to another country during the incubation period prior to clinical presentation. Domestic cases are patients that have not travelled outside Sweden.

Among the domestic cases, the median age was 44 years (0–96 years) and the incidence was highest for children younger than 5 years of age with 10.2 cases per 100 000 inhabitants followed by the age group of persons over 80 years with an incidence of 10.0 per 100 000 inhabitants.

Of the isolates from domestic cases, 88% were serotyped and the most common serovars among these were *S.* Typhimurium (30%), *S.* Enteritidis (17%), *S.* Agona (6%) and monophasic *S.* Typhimurium (6%). An additional 59 different serovars were identified in domestic cases during 2022. Of the cases infected in other countries, 18% were serotyped and *S.* Enteritidis was the most common serovar (59% of the isolates that were typed).

For domestic salmonellosis, a clear seasonality is usually observed, with most cases occurring during late summer and early autumn. In 2022, the number of domestic cases was low in early summer and summer and peaked only in September/October when a major outbreak occurred (see "Outbreaks" below). Travel-associated cases were at significantly lower levels than during the comparison period 2015–2019 and were at their highest in August. The low level of people infected abroad was particularly evident during the first months of the year when some more extensive travel restrictions still prevailed (Figure 46).

Outbreaks

In 2022, six outbreaks involving ten or more cases were identified, which is fewer than in 2021 when eleven such outbreaks occurred. Together, these outbreaks accounted for 29% (192/665) of the total number of reported domestic infections. For some, cases were reported over longer time periods, while others led to a larger number of cases in a short time, for example in September-October and November (see Figure 46).

Outbreak of S. Enteritidis, undercooked mixed minced meat patties

At the end of January, a local outbreak linked to a ski competition was reported in which teachers and students working as officials fell ill. WGS of isolates from the cases revealed a strain of *S.* Enteritidis very similar (differing by 5 SNPs) to one that had caused 14 cases of illness during 2019–2021. In 2021, that strain was also identified in chicken meat from Poland delivered to a fast-food restaurant chain. The investigation showed that the officials at the ski competition had eaten undercooked mixed minced meat patties. The meat patties were made from frozen mixed minced meat (beef and pork) originating from Poland/Slovakia but without eggs or poultry meat. Upon analysis of remaining minced meat from the same batch, the outbreak strain was identified. A total of eleven cases of illness were reported in the outbreak.

Outbreak of S. *Liverpool, frozen pre-cooked crayfish*

At the beginning of August 2022, *S.* Liverpool was identified from a sample taken at the Swedish border control post of frozen pre-cooked crayfish produced in China. The batch was withdrawn from the market before reaching consumers, but previously delivered batches from the same producer had been sold to consumers. Follow-up sampling at the border control post in August led to the discovery of salmonella in six additional batches. At the same time, human cases began to be identified with a strain of *S.* Liverpool that had previously been found in five cases in late summer-early autumn 2021, but without any cause being found. Interviews with the cases in 2022 showed that several had eaten crayfish before the illness, whereupon a connection between the findings in crayfish and the human isolates was confirmed by WGS. As the producer had only been approved for export in February 2022 and the importer had received crayfish from another producer in previous years, it was not possible to identify any connection to the cases in 2021. A total of 20 cases were reported in the outbreak, of which 15 were infected in 2022.

Outbreak of S. *Typhimurium, rocket salad*

In early October 2022, a rapidly growing outbreak of *S.* Typhimurium was identified via the microbial surveillance programme at the Public Health Agency of Sweden. In the previous weeks, a sharp national increase in the number of reported domestic cases with *Salmonella* serogroup B had been observed. Based on epidemiological data including information from interviews, questionnaire responses and collected receipts, a case-control study was conducted. The results showed that the outbreak cases had eaten rocket salad or, alternatively, bagged mixed salad originating from a specific food chain, before becoming ill. When Finland also turned out to have outbreak cases, several of which were linked to a specific restaurant, the traceback was facilitated and either of two Swedish producers could be identified as the likely origin. No clear cause for the products being contaminated could be identified, but a possible source could have been wild animals. In total, the outbreak included 109 Swedish outbreak cases.

Outbreak of S. *Agona, cucumber*

From mid-November 2022, an outbreak of *S.* Agona with cases from several different regions in Sweden was investigated. Interviews and questionnaire responses did not give strong clues about any specific source of infection other than that those who became ill commonly had bought their food at one or two of the major retail chains in Sweden. At the end of the month, Norway shared information through the European surveillance portal for infectious diseases, EpiPulse, about a major outbreak caused by *S.* Agona, whereupon it turned out that the Swedish outbreak cases, as well as cases from the Netherlands, carried the same strain. In Norway, a thorough tracing of products was carried out based on points of purchase, along with a case-control study. The results led to suspicion of Spanish cucumber as the source of infection, and it turned out that the same supplier had distributed products to the Norwegian, Swedish and Dutch markets. In total, 35 Swedish cases were reported in the outbreak and over 100 in other affected countries, mainly Norway.

Outbreak of S. *Enteritidis, eggs*

In addition to the outbreaks described above, a larger outbreak with *S.* Enteritidis linked to domestically produced eggs also began in 2022, although almost all cases were reported in 2023 (see “In focus”).

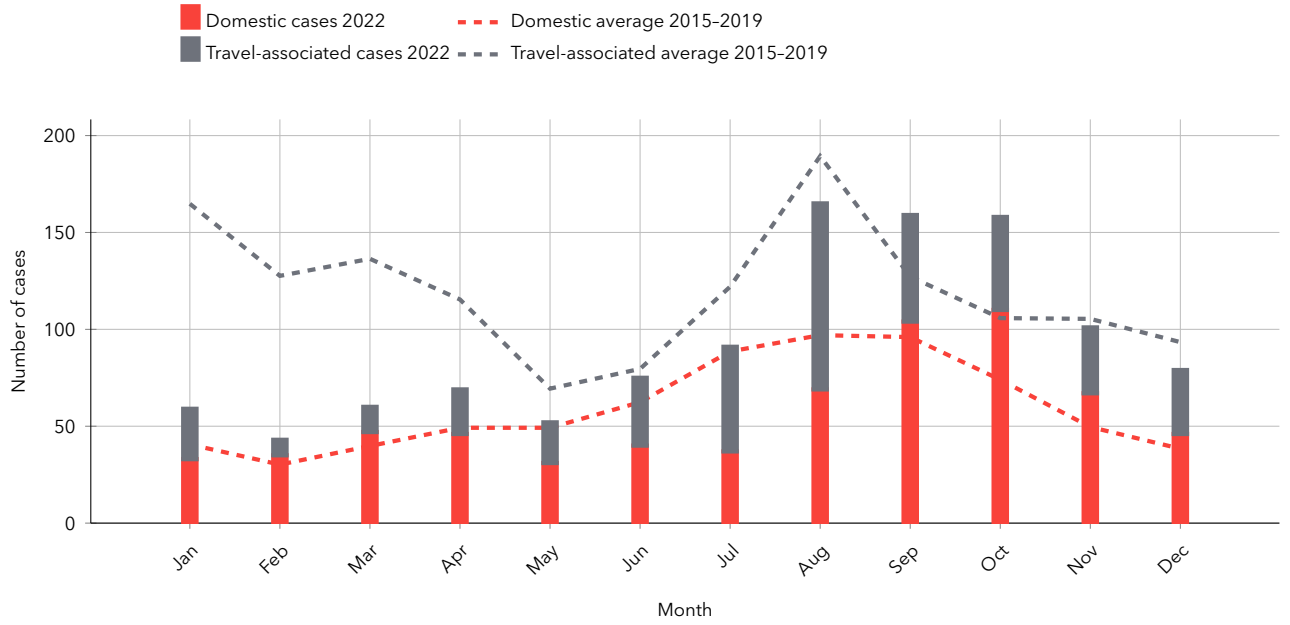

Figure 46: Monthly notifications of domestic and travel-associated human cases of salmonellosis in 2022 and a monthly average for domestic and travel-associated notifications in 2015–2019.

DISCUSSION

The low proportion of domestic *Salmonella* infections in humans is unique to the Nordic countries when compared to other European countries where such data is collected. This reflects the low *Salmonella* burden in domestic animals and food. However, between 2020 and 2022 the number of reported *Salmonella* cases in Sweden has halved compared with pre-pandemic numbers and, in addition, the proportion of domestically infected has become the majority (51, 76 and 58 percent of cases in 2020, 2021 and 2022, respectively). These changes are probably due to restrictions and changed behaviour during the pandemic, where travel restrictions, in particular, can be assumed to have played a major role.

In the feed sector, in 2022, as in previous years, several different serovars were isolated in the weekly surveillance of feed mills where *S.* Typhimurium and *S.* Mbandaka were the most common serovars (n=10). The findings were from several different feed mills, and most of them from the feed material intake area. This illustrates the importance of handling feed materials in a proper way even if the feed materials have been negatively tested for *Salmonella*. An interesting finding was *S.* Choleraesuis in a Swedish organic rapeseed cake where the rapeseed was grown in a county where *S.* Choleraesuis had been detected in wild boars.

The number of positive cats in 2022 was similar to that which was detected in 2018–2020. In 2021 there was a marked reduction in the number of positive cats, with only 42 index cases. Cats are mainly infected by wild birds and in years when certain wild bird species are low, the transmission of salmonella to cats may also be reduced, which may have been the case in 2021.

In 2022, regional bulk milk screenings were used to follow up areas of special interest. This complements the national bulk milk screenings that are performed with several years' interval, and will be continued in 2023.

The Swedish *Salmonella* control programme has been in place for decades and has resulted in a very low *Salmonella* burden in domestic food producing animals. The structure of the programme has been largely unchanged since the 1990s and the aim of the programme is still that Swedish food of animal origin should be free of *Salmonella*. With the planned revision of the programme, the *Salmonella* control will be performed with a partly different approach than previously.

Good cooperation between the public health, food safety and veterinary sectors is crucial in outbreak investigations, in control, in surveillance as well as in the further developments of the surveillance programmes.

REFERENCES

Ernholm L, Sternberg-Lewerin S, Ågren E, Ståhl K, Hultén C. 2022. First detection of *Salmonella* enterica, serovar Choleraesuis in free ranging European wild boar in Sweden. Pathogens, Jun 24;11(7):723. doi: 10.3390/pathogens11070723.

European Centre for Disease Prevention and Control and European Food Safety Authority, 2017. Multicountry outbreak of Salmonella Enteritidis infections linked to Polish eggs, 12 December 2017.

European Centre for Disease Prevention and Control, European Food Safety Authority, 2020. Multi-country outbreak of Salmonella Enteritidis infections linked to eggs, third update – 6 February 2020.

Li S, He Y, Mann DA and Deng X. Global spread of Salmonella Enteritidis via Centralized sourcing and international trade of poultry breeding stocks. Nat Commun. 2021 Aug 25;12(1):5109.

Pijnacker R. et al. An international outbreak of Salmonella enterica serotype Enteritidis linked to eggs from Poland: a microbiological and epidemiological study. Lancet Infect Dis. 2019 Jul;19(7):778–786.

Söderlund R, Jernberg C, Trönnberg L, Pääjärvi A, Ågren E, Lahti E (2019) Linked seasonal outbreaks of *Salmonella* Typhimurium among passerine birds, domestic cats and humans, Sweden, 2009 to 2016. Euro Surveill 24 (34) pii=1900074. https://doi.org/10.2807/1560-7917.ES.2019.24.34.1900074.