Food Authority

Evaluation of *Salmonella* reduction in NSW, 2015-2021

August 2026

Published by the NSW Food Authority

Title: Evaluation of *Salmonella* reduction in NSW, 2015-2021
First published: August 2026

Table of contents

Executive summary

In 2014, the Food Safety Strategy 2015–2021 was released with the overarching goal of safeguarding public health through improved food safety. One component of the strategy focused on reducing *Salmonella* infection, referred to as salmonellosis, which had increased prior to implementation, partly due to growing consumption of high-risk food items and the impacts of climate change, such as higher temperatures.

NSW Health and the NSW Food Authority collaborated to identify the sources of *Salmonella* outbreaks and develop measures to address them. The resulting *Salmonella* Reduction Strategy (SRS) combined policy development, improvements in training, evidence-based advocacy for vaccination in the layer industry, upskilling of enforcement officers and more rigorous control measures in response to incursion of *Salmonella* Enteritidis in egg layer flocks.

This document summarises the evaluation of the SRS, focusing on its estimated impact on the incidence rate of salmonellosis and whether the program was economically justifiable.

The evaluation used a forecasting approach to predict the rate of salmonellosis that would have occurred if the SRS had not been implemented. The model accounted for historical trends and seasonal patterns while reducing the influence of outliers. Forecasted incidence rates were then compared with observed rates after implementation to estimate the reduction in cases attributable to the SRS, with statistical testing used to assess whether differences were statistically significant. Adjustments were made to address the decline in notifications during the COVID pandemic. The SRS and the concurrent poultry vaccination campaign were evaluated jointly as a single coordinated intervention due to their interconnectedness.

This analytical approach estimated approximately 23% and 24% fewer cases of salmonellosis across the 2 evaluation periods analysed, equivalent to more than 600 fewer cases per month in NSW. The scale of the reduction was statistically significant, providing strong evidence that the observed decline was not the result of normal variation.

Quantification of the economic value of cases averted relative to program and vaccination costs also produced favourable results, with benefits significantly exceeding costs across both analysis periods analysed. For the longest period analysed, the program produced a benefit-cost ratio (BCR) of 8.1:1 and a net present value of $141.6m in 2025-dollar terms. The results are robust under conservative sensitivity assumptions and are expected to understate total benefits due to data limitations and the exclusion of several non-monetised impacts. While quantified benefits are distributed primarily to the NSW Government and the public, the analysis indicates strong value for investment in the program from a statewide perspective.

The success of the SRS demonstrates the benefits of articulating a shared goal and reduction target. While many factors in salmonellosis rates are beyond the direct control of any one single stakeholder, developing an evidence base and partnerships to influence multiple interventions across the supply chain is crucial to achieve sustained and significant benefits in human and economic terms.

Background

Food Safety Strategy

Released in 2014, the NSW Government Food Safety Strategy 2015–2021 (PDF, 2.7 MB) was a comprehensive framework aimed at safeguarding public health by ensuring a high standard of food safety across the state. It set out the trends, opportunities and challenges faced by the NSW food industry at the time and how the Food Authority would add value through the supply chain to promote the industry and consumer safety.

The high-level goals of the Food Safety Strategy were to:

- increase food business' contributions to NSW's economic growth and prosperity
- mitigate risks and protect the safety of NSW consumers
- improve the clarity and accessibility of food information provided to NSW consumers and industry.

A key component of the Food Safety Strategy 2015–2021 was the targeted reduction of salmonellosis by 30%. This evaluation investigates the success of the NSW Government's activities aimed at reducing salmonellosis.

Salmonella Reduction Strategy

The SRS was developed to guide actions to reduce the burden of foodborne illness in NSW through a coordinated approach combining surveillance, regulation, education and industry engagement. The SRS focused on addressing major transmission pathways associated with *Salmonella*, particularly contamination linked to egg production and the preparation of raw egg foods in retail settings. Early implementation was informed by epidemiological analysis of notification and outbreak data, which demonstrated clear associations between rising salmonellosis incidence rates and poor sanitation practices in food retail environments.

Policy development under the SRS prioritised risk reduction at source. Food safety guidelines were introduced to restrict the preparation and sale of raw egg foods unless businesses applied microbiological risk reduction processes, such as acidification or heat treatment. These guidelines were developed through cross-agency collaboration and were supported by interpretation of the Australia New Zealand Food Standards Code requirements for pathogen control in potentially hazardous foods. The regulatory approach aimed to reduce opportunities for *Salmonella* survival and transmission in commonly consumed high-risk foods.

Workforce capability was strengthened through mandatory training requirements for food service operators. Food Safety Supervisor training, which has been required in NSW retail food businesses since 2010, was enhanced with targeted modules addressing cleaning and sanitising practices and safe handling of raw egg products. These modules were incorporated into Registered Training Organisation curricula and delivered from 2015 onwards. Environmental Health Officers across local councils also received specialised training to improve inspection consistency and compliance monitoring across the state.

Industry engagement played an important role in strategy implementation. The NSW Government played a key advocacy role in promoting voluntary industry vaccination uptake as a primary prevention measure. Engagement through the Egg Industry Consultative Committee supported information sharing and evidence linking illness cases to egg layer flocks. These efforts have contributed to industry adoption of vaccination, which now covers a large majority of layer hens in NSW.

The strategy also included biosecurity responses to emerging pathogen threats. The detection of *Salmonella* Enteritidis in 2018 triggered outbreak investigations and the introduction of a Biosecurity Control Order requiring strict hygiene controls across egg and poultry farms. Mandatory testing of licensed egg farms was introduced to prevent pathogen establishment and further transmission. These measures successfully limited the spread of S. Enteritidis and reduced the risk of sustained endemic infection within NSW poultry populations.

Advocacy for vaccination formed part of the broader prevention framework. While regulatory and educational measures were central to implementation, industry uptake of voluntary vaccination programs played a key role in reducing contamination risk at source. Together, surveillance, regulatory controls, workforce training, biosecurity enforcement and vaccination contributed to sustained reductions in salmonellosis and improved food safety outcomes across NSW.

Salmonella, its growing impact and the efficacy of intervention

Salmonella is a bacterium which is widely dispersed in nature. It can colonise the intestinal tracts of vertebrates, including livestock, wildlife, domestic pets, and humans, and may also live in environments such as water sediment. It is spread via the faecal-oral route and through contact with contaminated water.

Salmonella can cause gastrointestinal illness in humans, known as salmonellosis. It is a significant public health concern worldwide, primarily transmitted through contaminated food or water. There are 2 main types of *Salmonella:* typhoidal and non-typhoidal.

Typhoidal *Salmonella* causes enteric fever, a serious systemic infection that can lead to high fever, prolonged illness and complications such as intestinal perforation or septicaemia. These *Salmonella* serotypes, such as S. Typhi and S. Paratyphi, are rare in Australia, where it is usually imported via travellers returning from countries with lower sanitation standards. In 2014, only 45 cases of typhoid fever were reported in NSW out of a total of 4,313 *Salmonella* notifications, amounting to approximately 1% of the state's cases (Ward et al., 2015).

Non-typhoidal *Salmonella* typically causes gastroenteritis, a less severe illness that involves symptoms like diarrhoea, vomiting, fever and abdominal cramps. This type of *Salmonella* is mostly transmitted by food (~80% of cases between 2001–2016), with environmental sources being responsible for the remaining cases (Ford et al., 2018). Eggs and egg-based products were primary vehicles prior to the implementation of the SRS and a mass vaccination uptake by the egg industry, identified as the cause in 71% of foodborne outbreaks with a known food vehicle in 2011 (OzFoodNet Working Group, 2015). Poultry, other meats, fruits and vegetables also contribute to the transmission, though to a lesser extent. Additionally, environmental factors such as soil, water and wildlife, such as kangaroos and birds, can play a role in transmission.

Economic and social impact

The economic and social impact of salmonellosis in Australia is considerable. In 2015, the total cost of salmonellosis, including direct healthcare costs and indirect costs such as lost productivity, was estimated to be AU$161 million (Australia National University, 2024). This includes hospitalisations, general practitioner visits, medication, treatment for complications like irritable bowel syndrome and reactive arthritis, absenteeism and premature mortality. A more recent study (Glass et al., 2023) estimated non-typhoidal *Salmonella* alone to cost Australia AU$140 million in 2019.

In addition to the health burden, salmonellosis poses a challenge to food industries, particularly in sectors like poultry, eggs and food service. *Salmonella* contamination can result in recall of goods, waste, lost consumer confidence, and fines or legal action. Food Standards Australia New Zealand (FSANZ) sets food standards for Australia with national, state and local governments sharing the responsibility of continuously monitoring and enforcing requirements to mitigate the risk of outbreaks. Public health strategies aim to reduce both the incidence of infections and the associated costs to the healthcare system.

Before the introduction of the SRS in 2015, notifications of salmonellosis in NSW were on the rise. Between 2000 and 2013, NSW saw an annual increase in S. Typhimurium and non-S. Typhimurium salmonellosis notification rates of 7% and 4% per annum, respectively, making it one of the states with the fastest growth in incidence (Ford et al., 2016).[1] This increase was in part driven by:

- the growing consumption of high-risk food items like eggs, poultry and processed foods (Australian Chicken Meat Federation, 2023; Australian Eggs, 2024)
- the impacts of climate change, as higher temperatures and more frequent and severe El Niño conditions have been shown to increase the incidence of salmonellosis (Davis et al. 2022).

[1] *Salmonella* Typhimurium is the most common serotype, responsible for about 40% of notifications from 2000 to 2013.

Control strategies

Reducing salmonellosis requires a comprehensive approach involving food safety regulations, on-farm controls and proper food handling practices (Food Standards Australia New Zealand, 2018). Regulatory frameworks help ensure that food producers and processors follow strict hygiene and safety standards to minimise contamination risks. On-farm measures, such as poultry vaccination, improved sanitation and regular testing, help control *Salmonella* at the source. Additionally, maintaining proper temperature control during storage and transportation, along with careful handling of raw products, reduces bacterial growth and cross-contamination.

Public awareness, testing and surveillance are also crucial in controlling *Salmonella.* Education campaigns promote safe food handling, particularly for high-risk foods like eggs and poultry. Surveillance programs monitor outbreaks and trends, guiding targeted interventions to reduce transmission. Effective traceability and recall systems help quickly identify and remove contaminated products from the market. By integrating these strategies, foodborne salmonellosis can be significantly reduced, improving public health and food safety worldwide.

A prominent example of government intervention managing and reducing the burden of *Salmonella* is the European Union's (EU's) comprehensive approach. In the early 2000s, the EU implemented an integrated strategy that included:

- enhanced monitoring and surveillance, including annual surveys to assess the prevalence of *Salmonella* in animals, food and human cases
- regulation of food safety primarily targeting *Salmonella* prevalence in poultry flocks, supported by strict control measures and regular inspections
- public awareness campaigns to educate the public and industry stakeholders about the importance of food safety and hygiene practices (European Food Safety Authority, 2017).

This strategy led to a 50% reduction in human salmonellosis cases between 2005 and 2009. The EU's success demonstrates how coordinated efforts across public health, agriculture and food safety sectors, and evidence-based decision making can effectively reduce the prevalence of *Salmonella*. The EU's model of collaboration, monitoring, and data-driven action serves as a key example of how public health threats can be tackled through a comprehensive, multi-faceted approach.

While the NSW Government had played an active role in controlling *Salmonella* prevalence prior to the implementation of the *Salmonella* Reduction Strategy, concerning increases in the incidence rate of *Salmonella* and indications this would continue necessitated further intervention.

Method for estimating salmonellosis incidence

Data summary

Salmonellosis notifications in NSW residents — NSW Ministry of Health[2]

Salmonellosis data is recorded by health service providers across Local Health Districts and published by the NSW Ministry of Health. The data is typically updated every 2 days, with frequent auditing and duplicate removal processes to ensure its accuracy. This forms the foundational data set for measuring the impact of the SRS. Monthly data from January 1991, the first month for which data is available, to May 2021 was used to maximise the number of observations for fitting the forecasting model and comparing against forecasted figures.

Salmonellosis case data is incomplete because only a small portion of people who get sick seek medical care. Many people suffering from gastroenteritis caused by non-typhoidal *Salmonella* do not

[2] Salmonellosis notification data is publicly available via the NSW Health website. Data was extracted on 20 March 2025.

seek medical attention and are unlikely to be tested if they do present. Research indicates that only 1 in 7 salmonellosis cases in Australia are recorded (Hall et al., 2008). This multiplier will be used alongside reported cases of salmonellosis to estimate the true impact of the SRS.

Salmonellosis notifications by serotype — NSW Ministry of Health

The NSW Ministry of Health maintains detailed salmonellosis case data, including serotype information, which is critical for evaluating the separate impact of the SRS and the *Salmonella* Typhimurium vaccination efforts of the egg industry.

Serotyping — the classification of *Salmonella* strains — is not performed for all notified salmonellosis cases. *Salmonella* serotype records prior to May 1993, are particularly incomplete, with fewer than two-thirds of cases having serotypes identified. Due to this limitation, pre-May 1993 data has been excluded to from the analysis to ensure a representative sample.

From May 1993 to May 2021, 201 distinct *Salmonella* serotypes were recorded in NSW. Of these, *Salmonella* Typhimurium makes up 52.2% of all notifications, with the remaining 47.8% distributed unevenly among the other 200 serotypes. Where serotyping information was incomplete, expert opinion was sought to assess whether the available serotyping data was consistent with S. Typhimurium.

Although an increase in the use of PCR testing from 2014 led to a decline in serotyping rates, these remained above two-thirds of all cases. Combined with an increase in total notifications, this supports the assumption that the serotype data remains broadly representative despite changes in testing practices.

For the purpose of this evaluation, it has been assumed the available data is representative of the broader population of salmonellosis cases, including those that were not reported nor recorded.

Historical NSW population — Australian Bureau of Statistics (ABS)[3]

National, state and territory population data was collected and calculated using a combination of census data, administrative records and statistical modelling to provide accurate, up-to-date, quarterly population estimates. The ABS regularly updates these figures, incorporating adjustments for factors such as births, deaths and migration. This dataset was utilised to ensure comparability of salmonellosis notifications over time by converting the data into a rate per 100,000 NSW residents.

Population data from Q4 1990 to Q2 2021 was utilised to convert salmonellosis case data into incidence rates. To align with the monthly salmonellosis notification data, the quarterly population figures were transformed into monthly estimates using a simple linear averaging method.

Analytical method

Baselining pre-implementation salmonellosis

Salmonellosis notification data exhibited an upward trend in the years leading up to the implementation of the SRS, with some notable outliers in the historical data. These qualities made it untenable to use the pre-implementation year of 2014 as a baseline, which was the recommended method in the original evaluation plan, particularly as 2014 itself appeared to be an outlier in terms of case numbers.

To overcome this baselining issue, a forecasting method was employed, using salmonellosis incidence rates as the key input. This method essentially predicted the expected rate of salmonellosis among the NSW population if the SRS had not been implemented. The forecasts were then compared to the actual data to evaluate the SRS's effectiveness.

[3] Quarterly population data is publicly available via the ABS website. Data was extracted on 20 March 2025.

Forecasting method

Along with an upward trend, the historical salmonellosis incidence rate data revealed regular seasonality, with peak periods occurring during summer and autumn months, primarily due to higher average temperatures. Therefore, any forecasting method used needed to account for both trends and seasonality.

The presence of apparent outliers immediately prior to the SRS's implementation ruled out forecasting methods that heavily emphasise the importance of more recent observations, such as exponential smoothing. Instead, an autoregressive integrated moving average (ARIMA) model was selected as it is well-suited to trending, seasonal data that ostensibly has late outliers.

The salmonellosis incidence rates used as inputs to the ARIMA model covered the period from January 1991 to September 2016. The first observation corresponds to the earliest month for which salmonellosis data is available, while the last observation is exactly 1 year after the first Strategy activity was implemented. This final observation was chosen based on several considerations, including the:

- staggered rollout of the SRS, with activity launches beginning in September 2015 and continuing through to September 2018
- anticipated delay between the implementation of the SRS's activities and a subsequent reduction in salmonellosis cases
- combination of limited pre-implementation data and a long evaluation period, which raised concerns about the accuracy of forecasts beyond the 60th point, thus necessitating the extension of the pre-intervention period past the SRS's launch.

This approach ensured the ARIMA model was applied in a way that considered both the characteristics of the data and the complexities of the SRS's implementation timeline.

Testing of the forecasting method over a period comparable to the one used for evaluation demonstrated a high degree of accuracy, with only a 16.6% discrepancy between forecasts and actual cases prior to implementation. The method tended to underestimate salmonellosis cases. This conservative bias enhances the method's credibility, ensuring that it delivers realistic and cautious predictions.

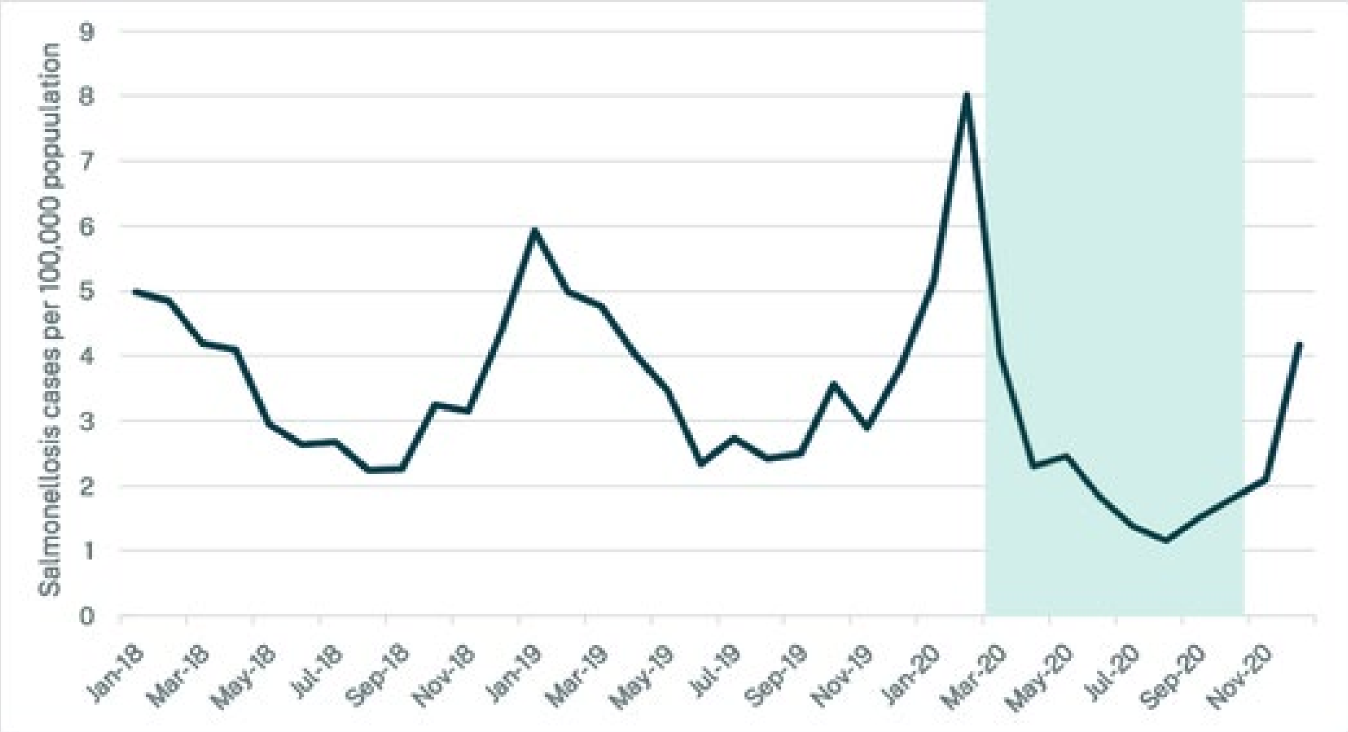
The forecasting model is described in greater detail in the technical note provided in the appendix.

Comparison between forecasts and actuals

The point forecasts produced by the ARIMA model and historical salmonellosis incidence rate data were compared with the actual salmonellosis incidence rates following September 2016. This comparison aimed to assess the divergence of actual rates from the predicted rates, part of this reduction would be attributable to the implementation of the SRS. To do so, the differences between the forecasted rates and the actual observed rates for each corresponding month were calculated. Statistical significance testing was conducted to determine whether the differences observed post observation were substantial enough to indicate that they were not due to random variability.

One notable exception to this method of comparison is presented by the first NSW COVID lockdown period and subsequent months. In 2020, salmonellosis notifications in Australia significantly decreased, coinciding with the implementation of strict public health measures in response to the COVID pandemic, as highlighted in Figure 1. Davis et al. (2022) found that these measures, including restrictions on movement, social distancing, and the closure of restaurants and social gatherings, reduced opportunities for foodborne transmission, particularly from restaurants, which have been a major source of outbreaks in the past.

Figure 1: Monthly salmonellosis incidence before and during the early COVID period (January 2018–December 2020)



In addition to restrictions on social activities, heightened public awareness of hygiene, and increased hand and surface sanitation likely played a key role in reducing *Salmonella* transmission. The closure of restaurants, reduced travel and a focus on food safety may have further contributed to this decline. Although there were some concerns about underreporting due to changes in health service usage and laboratory testing during the pandemic, it is unlikely that this fully accounted for the observed reduction in notifications.

If left unaddressed, the sudden decline in reported cases of salmonellosis would have suggested that the effectiveness of the SRS and other *Salmonella* reduction activities increased during this period. However, this conclusion is unrealistic, given the decline coincided with the onset of the COVID pandemic and associated restrictions, which influenced both reporting and behaviour. To address this anomaly, several methods were considered. The two most viable options were:

- ending the evaluation period in the month prior to the implementation of NSW COVID restrictions (October 2016–February 2020), which would limit the potential impact of COVID-related disruptions on the data
- developing a COVID-adjusted forecast for the affected period (March 2020–November 2020), allowing for an extended evaluation period (October 2016–May 2021) while accounting for the specific impact of COVID on the data[4].

Estimates using both approaches have been produced and are presented side by side to illustrate the robustness of the results, despite the limitations posed by the COVID pandemic.

Analytical limitations

In 2014, the Australian egg industry commenced voluntary vaccination of layer hens targeting S. Typhimurium, the most common serotype linked to foodborne transmission. By 2019, over 70% of the NSW poultry flock was vaccinated against *Salmonella* Typhimurium (Bioproperties, 2020). The

[4] This period was identified due to salmonellosis incidence rates during this time being substantially below the lower bound of normal variation.

implementation of a vaccination campaign that immunised poultry flocks against the primary serotype of *Salmonella*, concurrent with the rollout of activity by the NSW Food Authority, complicated the evaluation of the SRS's outcomes.

Several approaches were devised to isolate the specific impact of the SRS on broader *Salmonella* incidence from the impacts of the contemporaneous vaccination campaign, all of which had significant shortcomings. Methods included:

1. Analysing case data attributable to non-Typhimurium *Salmonella* serotypes could be detected as the vaccination campaign.
2. Attempting to control for the effect of the vaccination campaign.
3. Estimate broad transmission vehicle.

Method 1. Focusing on non-Typhimurium Salmonella serotypes

This approach relied on the assumption that the SRS would have an impact on all food-based serotypes of *Salmonella.* Whereas the vaccination campaign would primarily influence S. Typhimurium cases and a minor impact on non-Typhimurium cases through cross-reactive immunity. Any observed reductions in non-Typhimurium cases could then be attributed to the SRS.

Discussions between NSW Health and Department of Primary Industries and Regional Development (DPIRD) identified several significant limitations with this approach.

- The method fails to account for the high variability in transmission pathways across over 2,500 non-Typhimurium serotypes, many of which are not primarily foodborne and are therefore unlikely to be affected by food safety interventions.
- The analysis aggregates all non-Typhimurium cases, introducing significant noise from environmental serotypes that dilute any potential signal from foodborne reductions. The assumption that the proportion of foodborne versus environmental transmission remained stable over time further oversimplifies the complex and dynamic transmission landscape.
- The method assumes a uniform impact of the SRS across all serotypes, despite likely differences in how interventions affect S. Typhimurium (poultry-associated) versus other serotypes. Yearly variations in serotype distribution, unrelated to the interventions, further complicate attribution.

Without stratifying the non-Typhimurium data or controlling for changes in surveillance or diagnostic practices, the method relies on simplifying assumptions that do not hold in practice. As a result, the absence of a detected reduction in non-Typhimurium salmonellosis does not provide reliable evidence about the effectiveness of the SRS.

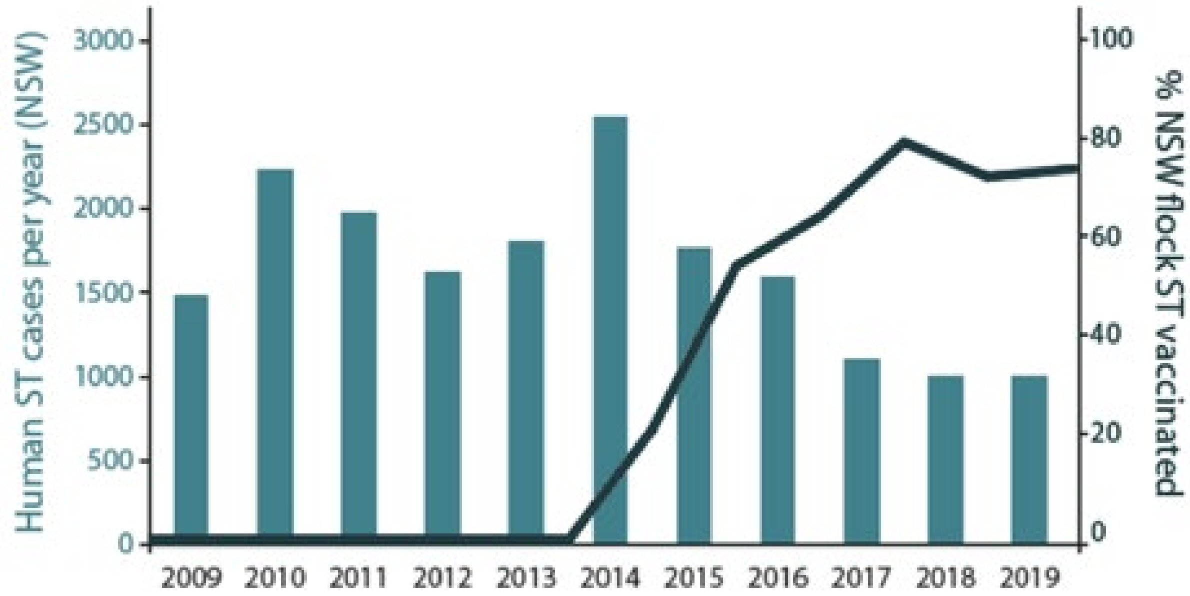
In summary, due to necessary simplifying assumptions that do not hold up to scrutiny, data aggregation and unaddressed complicating factors, this method lacks the analytical rigor needed to isolate the SRS's impact and is not a reliable basis for evaluation.

Method 2. Controlling for vaccination rates

An alternative method to isolate the SRS's impact involved adjusting the forecasting model to control for an independent variable, particularly flock vaccination rates. This approach would allow estimation of the relative contributions of both the SRS and the vaccination campaign. However, any synergistic effects between the two interventions would likely be attributed to the SRS alone, leading to an overestimation of its individual impact. Despite this limitation, the method was considered the most suitable for separating the effects of the two initiatives.

To implement this approach, monthly data on *Salmonella* Typhimurium vaccination rates in the NSW poultry flock was required. Bioproperties Pty Ltd, the vaccine manufacturer, provided only annual estimates, which were based on vaccine sales, flock size and recommended dosing (Figure 2).

Figure 2: Annual Salmonella Typhimurium cases (NSW) compared with the proportion of the layer flock vaccinated



Since the time-series forecasting method proposed depends on data that accurately captures month-to-month variation, annual figures could not be reliably disaggregated into monthly data for use in the model. Discussions with Bioproperties confirmed that vaccination data was not collected at a frequency sufficient to support this type of analysis. Additionally, the method used by Bioproperties to estimate the proportion of the flock vaccinated is unlikely to provide the accuracy required for forecasting. Vaccine sales data does not reliably reflect actual vaccine administration, as the timing of purchase may not align with the timing of use. For these reasons, controlling for vaccination rates was not a viable method.

Method 3. Estimating transmission vehicle by serotype

The final method considered to disentangle the impact of the vaccination campaign from that of the SRS involved estimating the proportion of salmonellosis cases by serovar attributable to foodborne versus environmental transmission routes. If feasible, this would allow the analysis to focus on foodborne cases associated with non-Typhimurium serotypes.

However, the complexity of *Salmonella* epidemiology poses significant challenges. Most serotypes can be transmitted through both routes (food or environmental) and over 2,500 serotypes have been identified globally. Even when narrowing the focus to the top 50 serotypes by human case volume in NSW, capturing the changing nature of transmission pathways over time would require strong simplifying assumptions, particularly that the proportion of cases attributable to each route remains constant. Compounding this issue, there is limited empirical evidence in the academic literature to support precise attribution, necessitating reliance on expert opinion. As a result, once assumptions and estimated proportions are applied to the case data, the output risks straying too far from reality to serve as a robust basis for evaluation.

Final approach

Each of the methods devised to isolate the impact of the SRS from that of the vaccination campaign was infeasible due to some combination of data limitations and methodological flaws. The timing of interventions, their interactivity, their similar purposes and the dearth of sufficiently granular data render attempts to disaggregate their individual contributions questionable.

However, the first three of these factors are not coincidental. As outlined in the Background section, NSW Health and DPIRD played an active role in analysing outbreak data, identifying links between *Salmonella* Typhimurium cases and egg layer flocks, and communicating this evidence to industry through formal consultative channels. This evidence base directly informed both the regulatory and training reforms under the SRS and the subsequent industry decision to adopt voluntary vaccination of breeder and layer flocks. The vaccination campaign was therefore not an independent development, but a response shaped and encouraged by government-led surveillance, advocacy and policy signalling. In this context, attempting to evaluate the SRS separately from vaccination would artificially separate interdependent measures that were conceived and implemented as part of a coordinated strategy to reduce *Salmonella* at source and along the food chain.

This coordination of efforts supports the decision to treat the SRS and vaccination campaign as complementary components of a broader, unified intervention. Evaluating them together therefore provides a more realistic and analytically defensible assessment of their impact. The other features of the evaluation approach, such as the evaluation period, forecast method and COVID smoothing, are consistent with the approach of treating the SRS and vaccination campaign as a single intervention and have been implemented in the following analysis.

Findings

Forecasted versus actual salmonellosis

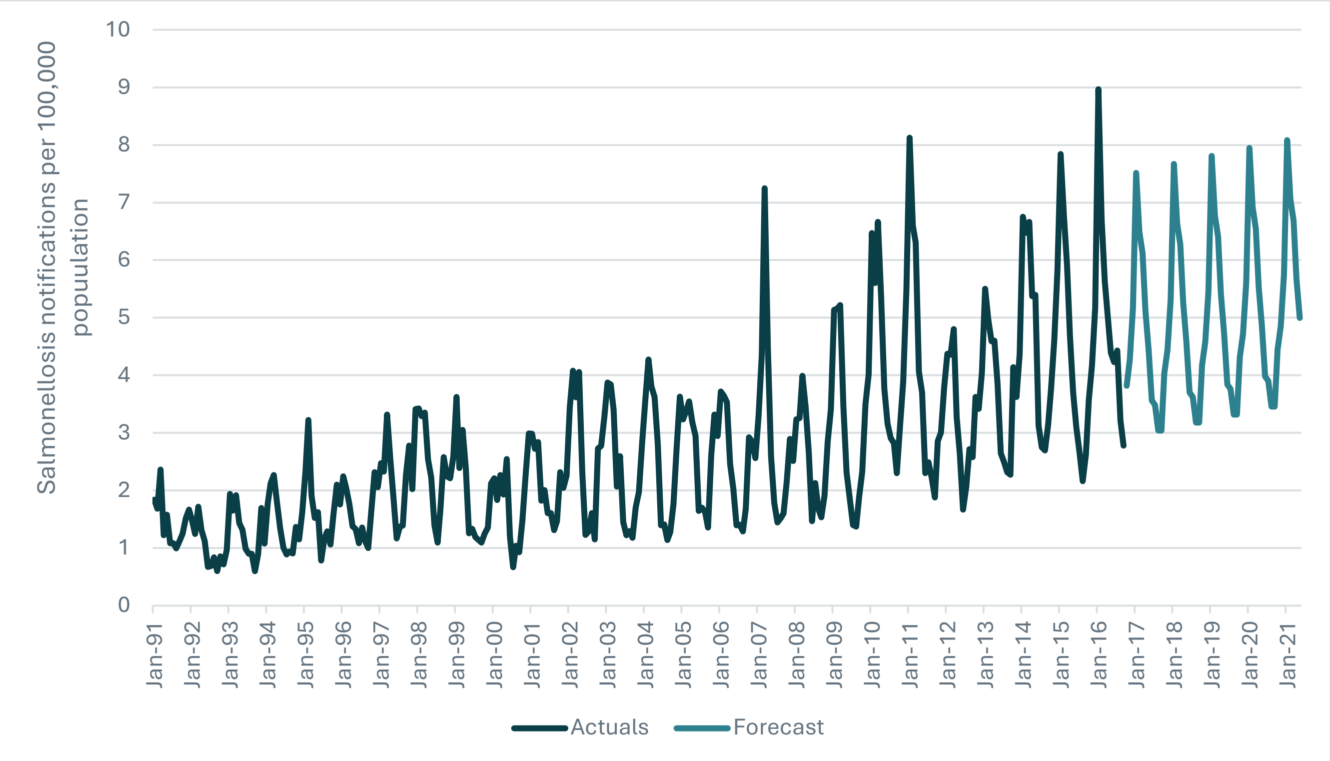
Baseline forecast

The auto-fitted ARIMA model (Figure 3) projected a relatively moderate incidence rate for the first forecast year compared with the two preceding years of observed salmonellosis data, in which monthly notifications peaked at approximately 8 and 9 cases per 100,000 population, respectively.

The historical time series demonstrates a clear upward trend with consistent seasonality, including recurrent summer peaks. Outliers are also evident, usually reflecting irregular outbreak activity. The ARIMA model captured the underlying trend and seasonality while smoothing extreme values, given that sudden outbreak-related spikes cannot be explicitly modelled with this method.

Overall, the baseline forecast provides a conservative counterfactual trajectory of expected incidence in the absence of intervention.

Figure 3: Observed historical salmonellosis rates per 100,000, forecast from the start of the evaluation period

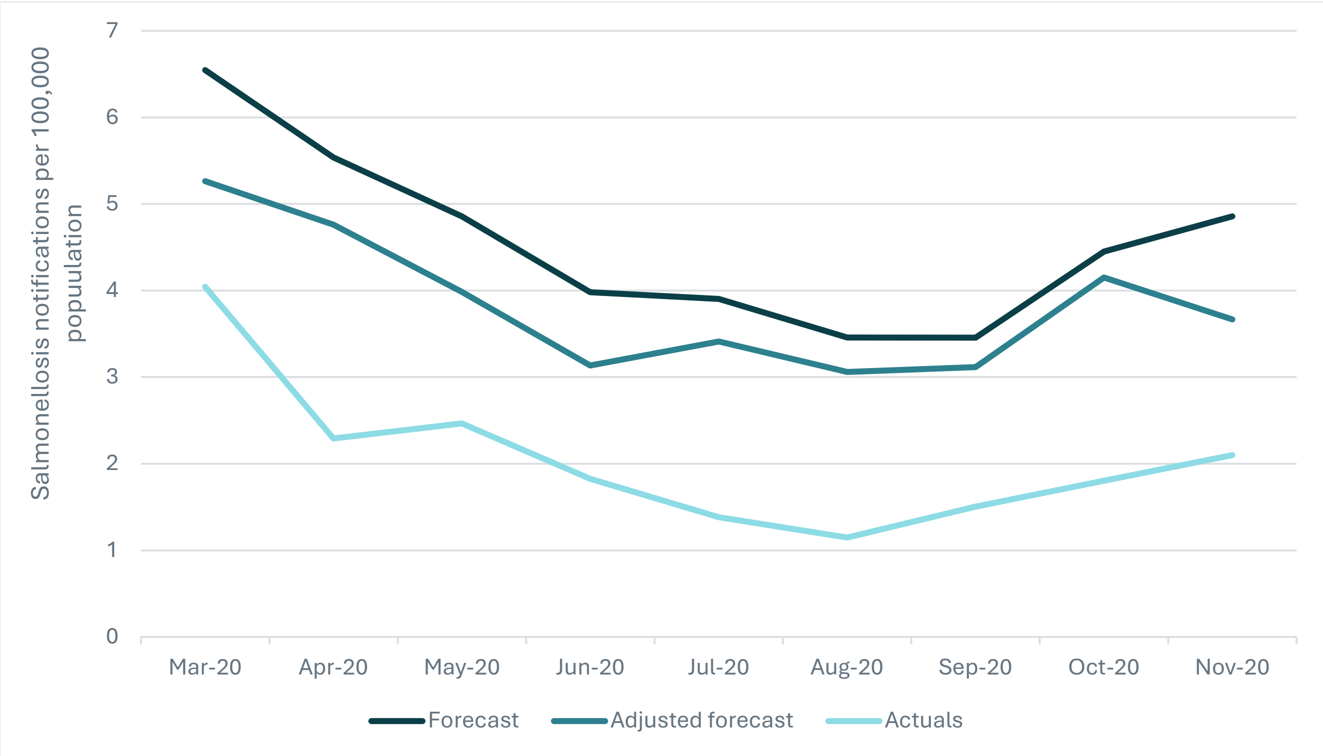


COVID-adjusted forecast

During and in the months following the 2020 COVID lockdown in NSW, reported salmonellosis rates per 100,000 population declined sharply, reaching levels not observed since 1993. To account for the distorting effects of COVID, an adjusted forecast was developed using predominantly post-implementation salmonellosis rate data to approximate a counterfactual scenario in which COVID-related disruptions did not occur. The adjusted forecast, used as a proxy for actual rate data, aligns much more closely with the originally projected salmonellosis rates than the observed rates, as shown in Figure 4.

By adopting this conservative approach, the evaluation provides a more reliable estimate of program outcomes and enables the use of an extended evaluation period.

Figure 4: Forecasts compared with observed salmonellosis rates during the COVID-affected period



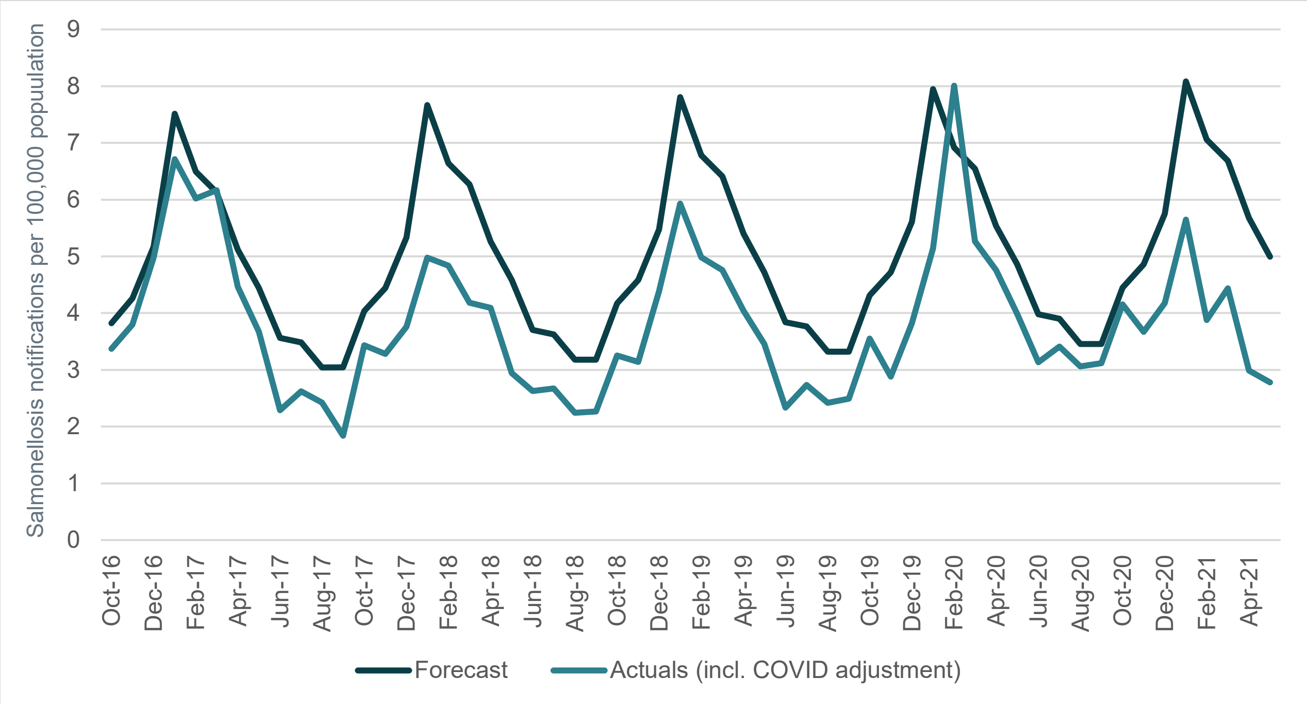
Forecast comparison with actuals

Across all analysed years, forecasted salmonellosis incidence exceeded observed rates, as displayed in Figure 5. The closest alignment between forecasted and measured rates occurred during the:

- first evaluation year (October 2016–September 2017)
- period spanning the initial COVID lockdown and immediate recovery (March 2020–November 2020).

The early similarity likely reflects the gradual accumulation of effects from the egg industry vaccination campaign and SRS, with full program impact emerging over time. The later convergence during the COVID period is attributable to the use of proxy-adjusted rates to avoid artificial inflation of estimated intervention effects due to exogenous factors that reduced the likelihood of salmonellosis and notification.

Figure 5: Comparison between forecasts and actuals over the longest evaluation period

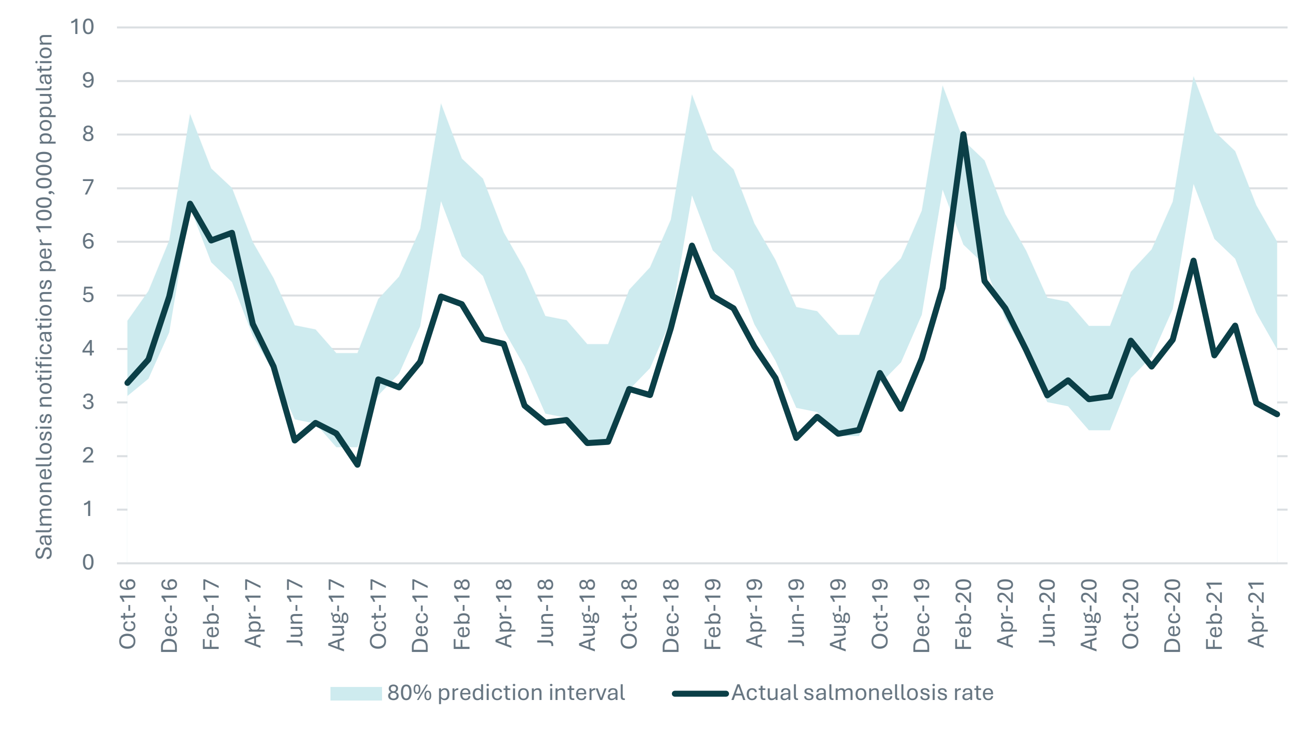


February 2020 represents the only point during the evaluation period at which the observed salmonellosis notification rate exceeded the forecasted rate. The seasonal peak in 2020 occurred later than the historical norm, which is typically observed in January, and is largely attributable to a national outbreak of *Salmonella* Typhimurium, of which 230 cases were identified in NSW (OzFoodNet, 2022). While the February 2020 rate exceeded recent seasonal peaks recorded since implementation of the SRS and vaccination campaign, it remained substantially lower than pre-implementation peaks.

Prediction intervals

To test the sensitivity of the evaluation results, an 80% prediction interval was generated, representing the range within which observations would be expected to fall with 80% probability. As shown in Figure 6, for most post-intervention months the lower bound of the prediction interval remains above the observed salmonellosis notification rate with the difference being determined to be statistically significant. This result highlights the robustness of the evaluation result, demonstrating that even under a very conservative counterfactual, observed notification rates remain sufficiently below expected levels in the absence of the intervention that the difference cannot be attributed to random variation. However, this result is sensitive to the confidence threshold applied and would not be retained if a 95% prediction interval were adopted.

Figure 6: 80% prediction interval (P.I.) compared with observed salmonellosis rates



This result should be placed within context to clarify its significance. The lower bound of the 80% prediction interval implies a sharp post-intervention decline in salmonellosis rates to levels last observed in 2012, effectively assuming that the subsequent four years (2013–2016) were outliers rather than part of an ongoing upward trend. Although observed salmonellosis rates in 2014 did appear to be outliers, this characterisation does not hold for 2013, 2015 or prior to the evaluation period in 2016. There is no clear basis to support such a pronounced and sustained reduction in rates. On the contrary, the structural drivers of *Salmonella* transmission identified in the Background section persist. For these reasons, while the lower bound of the 80% prediction interval represents an implausible counterfactual scenario, the results nonetheless continue to demonstrate a statistically significant program impact, reinforcing confidence in the evaluation findings.

Estimated reduction in salmonellosis cases

As tabulated below (Table 1), both evaluation windows demonstrate statistically significant reductions in incidence compared with forecasted counterfactual estimates, with observed salmonellosis cases approximately 23% lower than expected.

Table 1: High-level evaluation findings of impact on salmonellosis cases

Forecast period	% (actual vs. forecast)	Notification reduction	Total impact
October 2016–February 2020	22.7% less than expected (statistically significant)	3,673 fewer notifications 89.6 fewer per month	25,529 fewer cases 623 fewer per month
October 2016–May 2021	23.7% less than expected (statistically significant)	5,361 fewer notifications 95.7 fewer per month	37,256 fewer cases 665 fewer per month

A reduction of this size is substantial in communicable disease control terms. A sustained decrease of nearly one-quarter in expected incidence represents not only fewer sporadic infections, but also a dampening of seasonality and outbreak potential. After accounting for the7-to-1 underreporting ratio, this corresponds to an estimated 25,529 and 37,256 cases averted over the two evaluation windows, or around 650 cases prevented per month.

Importantly, the inclusion of the COVID-adjusted period does not materially alter the estimated magnitude of effect. The persistence of an approximately 23% reduction even after accounting for pandemic-related distortions indicates that the observed decline is unlikely to have been affected dramatically by temporary behavioural or environmental changes associated with COVID restrictions once comparisons between forecasts and measured rates resumed (from December 2020 onward). Rather, the findings support a sustained structural shift in salmonellosis incidence consistent with the implementation of the vaccination campaign and SRS.

This reduction in salmonellosis incidence has clear economic implications. The scale and consistency of the reduction provide a strong foundation for examining whether the financial investment in vaccination and Government action yields a positive return. The following section presents a cost-benefit analysis to quantify the economic value of cases averted and assess the overall return on investment.

Cost-benefit analysis (CBA)

In this analysis, CBA is applied to estimate the combined net economic impact of the mass vaccination campaign and the SRS on industry, government and the public over time. This approach allows for a systematic comparison of avoided health and productivity losses, program and implementation costs, and wider societal impacts, supporting evidence-based assessment of the overall value of the intervention in line with NSW Government guidance.

Two analysis periods have been used in this CBA, January 2014–February 2020 (pre-COVID) and January 2014–May 2021 (COVID adjusted), with a central discount rate of 5% and using FY25 dollars, as per requirements of the NSW Government Guide to Cost-Benefit Analysis (TPG23-08).

Key costs and benefits

Descriptions

There are 2 main costs that need to be considered within this analysis.

- Vaccination costs to industry, including injection at hatchery, at 6 weeks old and at 12 weeks old, as well as the 3 required vaccines.
- Strategy Reduction Strategy implementation costs to the NSW Government.

Three main benefit groups associated with the mass vaccination campaign and implementation of the SRS have been quantified in this analysis.

- **Avoided health system costs**, such as those associated with GP, specialist and hospital visits, primary care services, emergency and acute care, diagnostics, and treatment.
- **Avoided negative life impacts**, including premature death, productivity loss and leisure loss.
- **Avoided cost to industry**, including loss of production and treatment and management expenses.

Avoided costs to the health system and negative life impacts were determined for salmonellosis and *Salmonella*-induced conditions, particularly reactive arthritis (ReA) and irritable bowel syndrome (IBS). ReA and IBS can develop weeks after a *Salmonella* infection, triggered by the body's autoimmune response to the bacteria. Hence, by reducing salmonellosis cases, cases of ReA and IBS are also avoided. Table 2 summarises the estimated premature mortalities and cases of salmonellosis, ReA and IBS avoided under the central assumptions of this analysis.

Table 2: Estimated reduction in salmonellosis, related diseases and premature mortalities

Measure	Pre-COVID (Oct 2016–Feb 2020)	COVID-adjusted (Oct 2016–May 2021)
Salmonellosis	25,529 fewer cases	37,256 fewer cases
ReA	1,418 fewer cases	2,069 fewer cases
IBS	1,733 fewer cases	2,529 fewer cases
Mortalities	2 fewer premature deaths	3 fewer premature deaths

A range of other benefits were considered in the analysis, but not quantified, and are discussed in more detail in the next section.

Estimation methods

Benefits and costs were estimated using evaluation results, available information from academic literature via a desktop study and advice from subject-matter experts within DPIRD Food Safety, NSW Ministry of Health and Bioproperties Pty Ltd. Table 3 below summarises the basis for the estimation of costs and benefits considered within this CBA. Comprehensive tables of cost figures and impacts of salmonellosis, ReA and IBS are provided in the appendix. All monetary figures are presented in 2025 dollars.

Table 3: Summary of estimation methods, including key estimates and sources

Cost or Benefit	Calculation method	Key estimates used[15]
Costs		
Program costs	Amount of funding provided to deliver program components, including policy development, staffing and training, surveillance and compliance activities, industry engagement, and communications.	$1.3 million–$1.5 million in program costs over the course of FY14–FY21 (range depend on the analysis period).
Vaccination campaign	Total layer and broiler chicken flock over the course of each year multiplied by the vaccination rate for that year. Estimate uses this vaccinated flock number and the cost of vaccines and their administration.	$0.43 to fully vaccinate each chicken (provided by C. Morrow, Bioproperties Pty Ltd, personal communication, 1 September 2025). Average flock size of 5 million over analysis period (DPI Performance Data and Insights, 2022). Average vaccination rate of 64% over the analysis period (Bioproperties Pty Ltd).
Benefits		
Avoided costs to industry	Adjust revenue losses and additional costs to current conditions by scaling	Average number of layer chickens over analysis period: ~5,000,000 (DPI Performance Data and Insights, 2022).

	them to the change in national layer hen population since 2007. Allocate the national estimate to NSW using NSW's share of the national layer flock, and scale up to represent the full industry rather than just the survey sample. Estimate avoided profit losses by multiplying the NSW *Salmonella* impact by the projected percentage reduction in salmonellosis cases.	Annual reduction in Australian poultry layer industry income and expenses due to *Salmonella*: $2.1 million and $7.9 million, respectively (Lloyd, 2008). Proportion of poultry layer industry in NSW: 36% (FSANZ, 2025).
Avoided health system costs	Reduced cases of *Salmonella* due to the SRS and vaccination campaign estimated via evaluation approach. Reduction in *Salmonella*-induced conditions including ReA and IBS calculated using average likelihoods. Health system costs avoided calculated using reduced need for a variety of primary care, treatments, diagnostics, etc. and associated unit costs.	Tables of average percentages of salmonellosis and related cases seeking treatment or medication are available through an appendix by Ford *et al.* (2019) — Supplemental Material 1. Tables of average costs are available through an appendix by Ford *et al.* (2019) — Supplemental Material 2. Average daily cost of hospitalisation: $2,445 (National Hospital Cost Data Collection, 2025). Average cost of GP and non-admitted ED presentation: $87 and $730, respectively (General Practice Health of the Nation, 2024).
Avoided negative life impacts	Avoided cases of salmonellosis, ReA and IBS multiplied by associated case fatality rates and average days of lost leisure and productivity.	Value of a statistical life: $5,863,082 (NSW Treasury Outcome Values Database, 2024). Likelihood of fatality and average days of lost work and activities are available through an appendix by Ford *et al.* (2019) — Supplemental Material 1. Average daily wage across males and females: $410 (ABS, 2025). Average number of hours spent on leisure per day: 4.4 hours (ABS, 2021). Average willingness to accept an hour less leisure: $31 (Verbooy *et al.*, 2018). Average health and life impacts of salmonellosis, ReA and IBS varied by disease. Estimates are provided in the appendix.

Additional costs considered in preparation of this CBA that could not be quantified with an acceptable degree of confidence or accuracy include:

- **Marginal increases in costs for businesses and local councils** to complete training, accreditation and/or education. This is expected to be minimal, as the SRS improved the quality of training without increasing the amount required.
- **Marginal surveillance testing or investigation costs arise** from more intensive surveillance or investigation practices required by the SRS, particularly in relation to the incursion of *Salmonella* Enteritidis in 2018. These incremental costs for laboratories, producers and regulatory authorities build upon existing surveillance systems and investigative practices.

Additional benefits not able to be quantified in the analysis include:

- **Avoided outbreak-related costs to Government** which result from reducing the likelihood and severity of foodborne *Salmonella* outbreaks. Fewer outbreaks mean avoiding substantial expenditures on emergency responses and public health measures, although these benefits vary depending on the size of avoided outbreaks. This was not quantified due to poor quality outbreak data. An outbreak response typically costs the Government about $5,500 for food sample testing and $8,600 in staff time (2025), totalling approximately $14,000. During the analysis period, there were 9–26 outbreaks per year.
- **Lower recall costs** because fewer contamination events reduce the need for product recalls. This avoids financial losses and logistical challenges associated with withdrawing, disposing of and replacing affected goods.
- **Reduced costs for retail, hospitality and other food businesses** that may otherwise handle or sell products contaminated with *Salmonella*. Such costs include disposal and cleaning expenses, staff downtime, reputational damage, customer refunds and the administrative burden associated with incident investigations and compliance actions.
- **Strengthened consumer confidence and sustained market access** because improved food safety performance helps maintain public trust and supports access to domestic and international markets. While the benefits of consumer confidence in the egg industry are difficult to quantify, they have clear and material impacts on farm profitability and sustainability. Declines in industry reputation can significantly reduce sales over extended periods, and rebuilding that trust is often slow and challenging.
- **Long-term public health benefits** from reduced baseline *Salmonella* prevalence since lowering contamination at the source contributes to fewer sporadic community cases of salmonellosis. These benefits are diffuse and challenging to attribute directly but improve population wellbeing and may reduce long-term pressures on the health system that are distinct from care costs, which have been monetised.

A reduction in the number and size of hygiene-related fines was also considered, but deemed to have a net-zero effect, as it represents a transfer of funds from industry to the NSW Government rather than a true economic gain or loss.

If these additional benefits and costs were included in the analysis, the NPVs and BCRs could be expected to be higher than outlined in this business case. For this reason, the results presented below are considered conservative.

CBA results

The tabulated results below (Table 4) summarise the quantifiable incremental costs and benefits of the program from January 2014–May 2021. In terms of costs, these are limited to costs associated with the SRS development and implementation and those for the rollout of the vaccination campaign. Quantified benefits include avoided costs to industry from reduced revenue and increased expenses due to *Salmonella* affecting operations, avoided costs to the health system from less need for medical care, and avoided costs to quality of life and productivity. In addition to the quantified results, there are qualitative costs and benefits that could not be accurately monetised. If these were incorporated into the CBA model, they are expected to favour the benefits, increasing the NPV and potentially BCR.

Table 4: High-level CBA results

Present value at 5% discount rate (2014–2020)	Pre-COVID ($m)	COVID adjusted ($m)
Incremental costs (total)	**16.4**	**20.0**
Program costs	2.0	2.3
Vaccination campaign	14.5	17.7
Incremental benefits (total)	**115.0**	**161.6**
Avoided costs to industry	4.6	6.1
Avoided health system costs	23.7	33.4
Avoided negative life impacts	86.7	122.1
Life impacts: avoided premature deaths	17.0	23.9
Life impacts: avoided productivity loss	23.8	33.5
Life impacts: avoided leisure loss	35.6	50.1
Life impacts: willingness to pay to avoid suffering	10.4	14.7
NPV	**98.6**	**141.6**
BCR:1	**7.0**	**8.1**

At a high level, the results indicate that regardless of the analysis period, the SRS program in combination with the egg industry vaccination efforts has delivered a strong return on investment. The quantified benefits substantially exceed the costs, indicating that this investment by the NSW Government and industry was economically justified.

This result is achieved despite limited information on industry-level benefits, as commercially sensitive data on production losses and treatment costs are scarce. The estimates of avoided industry costs are drawn from a study that relied primarily on secondary literature, modelled disease incidence and expert elicitation rather than firm-level longitudinal data, and therefore capture only a portion of actual avoided losses.

In addition, the methodology excludes difficult-to-attribute losses (e.g. nutrition, environmental stress and peri-natal mortality), infrequent catastrophic outbreaks and relies on self-reported survey data without formal audit or extrapolation. As a result, the quantified benefits for industry should be interpreted as conservative estimates within the cost-benefit analysis rather than a comprehensive measure of total industry gains.

Table 5 presents the present value of benefits and costs, together with the resulting net present value, for the program across the two evaluation periods. The results show that the program's benefits exceeded costs from 2016 onwards and achieved breakeven early in 2017, with annual BCRs ranging from 7.9:1 to 14.5:1 from 2017.

Table 5: Annual present value benefits and costs and NPV

$m	2014	2015	2016	2017	2018	2019	2020	2021	Total
Pre-COVID (October 2016–February 2020)									
PV benefits	0.0	0.0	3.4	25.9	41.9	39.9	3.9	0.0	**115.0**
PV costs	1.2	2.8	2.8	3.3	3.1	2.7	0.5	0.0	**16.4**
NPV	-1.2	-2.8	0.5	22.6	38.9	37.1	3.5	0.0	**98.6**
Cumulative NPV	-1.2	-4.0	-3.5	19.1	58.0	95.1	98.6	98.6	
COVID-adjusted (October 2016–May 2021)									
PV benefits	0.0	0.0	3.4	25.9	41.9	39.9	22.5	28.0	**161.6**
PV costs	1.2	2.8	2.8	3.3	3.1	2.7	2.7	1.3	**20.0**
NPV	-1.2	-2.8	0.5	22.6	38.9	37.1	19.8	26.7	**141.6**
Cumulative NPV	-1.2	-4.0	-3.5	19.1	58.0	95.1	114.9	141.6	

Sensitivity analysis

A truncated sensitivity analysis has been undertaken as part of this CBA to determine the robustness of the results under a best- and worst-case scenario. These scenarios are characterised by the following conditions in combination:

- Discount rate
  - Worst case = 7%.
  - Best case = 3%.
- Costs associated with and likelihoods of a variety of medical care interventions and willingness to avoid pain and suffering.
  - Worst case: Lower bound estimates (95% confidence interval) presented in Ford et al. (2019).
  - Best case: Upper bound estimates (95% confidence interval) presented in Ford et al. (2019).
- Percent of industry represented in Lloyd (2008).
  - Worst case = 70%.
  - Best case = 50%.
- Proportion of industry expenses committed to non-prevention activities.
  - Worst case = 25%.
  - Best case = 75%.

The above parameter assumptions produced the results presented in Table 6.

Table 6: Sensitivity analysis results for worst- and best-case scenarios

	Pre-COVID		COVID adjusted	
Metric	**Worst case**	**Best case**	**Worst case**	**Best case**
NPV ($m)	52.5	178.1	76.3	256.6
BCR:1	3.7	13.7	4.3	15.8

The results indicate that even under stricter assumptions, the combined efforts of the SRS and egg industry vaccination have delivered net benefits regardless of analysis period. BCRs remain comfortably above 1:1 for both analysis periods, demonstrating that the investment is not overly sensitive to conservative parameter settings.

It should be noted that the 80% prediction interval bounds for the forecast used to simulate the counterfactual scenario were excluded from this analysis. This is because they reflect an implausible counterfactual, particularly for the lower bound, which implies a sharp decline in salmonellosis notification rates in 2016 to levels last observed in 2012, followed by a marked and sustained moderation of the established upward trend in notification rates.

Distributional analysis

Distributional analysis has been prepared as part of this CBA to demonstrate the stakeholders that accrue key costs and benefits. The distributional analysis is presented for the COVID-adjusted analysis period in Table 7.

Table 7: Distributional analysis results for primary stakeholder groups

$m (present value at 5% discount rate)	Industry	NSW Government	Public
Incremental costs (total)	**17.7**	**2.3**	**0.0**
Program costs	0.0	2.3	0.0
Vaccination campaign	17.7	0.0	0.0
Incremental benefits (total)	**6.1**	**28.8**	**126.7**
Avoided costs to industry	6.1	0.0	0.0
Avoided health system costs	0.0	28.8	4.6
Avoided negative life impacts	0.0	0.0	122.1
NPV	**-11.6**	**26.5**	**126.7**
BCR:1	**0.3**	**12.8**	**N/A**

Analysis of available data indicates clear net benefits to the NSW Government and the public, driven by reduced health system costs associated with salmonellosis, as well as avoided pain and suffering, productivity losses and premature mortality linked to salmonellosis and related conditions. Industry was the only stakeholder group for which a net benefit was not identified, likely reflecting an inability to quantify key industry benefits, especially consumer confidence and market access. This is compounded by a limited evidence base, including scarce data on commercial operations and the shortcomings of the Lloyd (2008) study.

Conclusion

Overall, the combined SRS and vaccination campaign is estimated to have delivered substantial net economic benefits, with quantified benefits significantly exceeding program and implementation costs across both analysis periods analysed. The results are robust under conservative sensitivity assumptions and are expected to understate total benefits due to data limitations and the exclusion of several non-monetised impacts. While quantified benefits are distributed primarily to the NSW Government and the public, the analysis indicates strong value for investment in the program from a statewide perspective.

Discussion

The scale and severity of increasing salmonellosis rates and foodborne illness in NSW, particularly from 2010–2014, necessitated an intervention. No single point of focus or stakeholder group in the supply chain would be able to reverse the increasing salmonellosis trend observed at the time. Through the efforts of the Food Safety Strategy 2015–2021, a stated reduction target was established.

While there were many factors and parameters beyond the control or influence of NSW government, articulation of the reduction target was an important step in setting a shared goal across all affected stakeholders. In partnership with NSW Health, common causes of salmonellosis outbreaks and epidemiological links to source were identified. This information formed the basis for mandatory training of foodservice workers, and a coordinated inspection and enforcement program across 130 local governments and food control authorities in NSW.

Major businesses and stakeholders in the egg industry were able to see the effect of increased prevalence of *Salmonella* (particularly *Salmonella* Typhimurium) in layer flocks on human salmonellosis rates. To the credit of the egg industry, voluntary vaccination of layer flocks against *Salmonella* Typhimurium was one of the single biggest factors in achieving a substantial reduction in foodborne illness. This has had a sustained impact on reduced rates and associated cost of illness in NSW and Australia more broadly (McClure *et al.*, 2022).

The detection of *Salmonella* Enteritidis on a layer farm in 2018 threatened to derail the efforts of the reduction strategy to date. If allowed to become endemic across the egg industry, *S.* Enteritidis would have become a significant foodborne hazard and likely resulted in thousands of extra cases of human illness. In partnership with the egg industry and NSW DPIRD, actions to control the spread of *S.* Enteritidis were effective and sustained.

Without this multidisciplinary approach to control of salmonellosis and a shared goal, the burden of foodborne illness in NSW would remain unacceptably high and a burden on resources. The ability to adapt to new challenges, such as detection of *S.* Enteritidis in 2018, was crucial in maintaining momentum and consolidating reductions in salmonellosis to date.

The partnership approach across government, primary industries, and the foodservice sectors to reduce human salmonellosis and subsequent economic benefits are a potential model for future interventions to reduce the burden of foodborne illness in Australia.

References

Australian Bureau of Statistics. (2022, October 7). *How Australians Use Their Time*. Australian Bureau of Statistics. URL: www.abs.gov.au/statistics/people/people-and-communities/how-australians-use-their-time/latest-release

Australian Bureau of Statistics. (2025, February 20). *Average Weekly Earnings, Australia*. Australian Bureau of Statistics. URL: www.abs.gov.au/statistics/labour/earnings-and-working-conditions/average-weekly-earnings-australia/latest-release

Australian Chicken Meat Federation. (2023). *T1 Facts and Figures*. Australian Chicken Meat Federation Ltd. URL: chicken.org.au/our-product/facts-and-figures/

Australian Eggs. (2024). *Australia's Egg Industry: Everything You Need To Know*. Australian Eggs. URL: www.australianeggs.org.au/egg-industry

Australian National University (2024). *The annual cost of foodborne illness in Australia by food commodities and pathogens Final Report.* URL: www.foodstandards.gov.au/sites/default/files/2024-09/ANU%20Foodborne%20Disease%20Attribution%20Final%20Report.pdf (PDF, 1.2 MB).

Bioproperties. (2020). *Protecting Consumers – ST Case Study*. Bioproperties Pty. Ltd. Unpublished case study.

Davis, B., Amin, J., Franklin, N., & Beggs, P. J. (2022). Salmonellosis in Australia in 2020: possible impacts of COVID-19 related public health measures. *Communicable Diseases Intelligence (2018)*, *46*. URL: doi.org/10.33321/cdi.2022.46.2

Davis, B., Amin, J., Graham, P., & Beggs, P. (2022). Climate variability and change are drivers of salmonellosis in Australia: 1991 to 2019. *Science of The Total Environment, 843*, 156980. URL: www.sciencedirect.com/science/article/pii/S0048969722040773

European Food Safety Authority. (2017). *Salmonella*. European Food Safety Authority. URL: www.efsa.europa.eu/en/topics/topic/salmonella

Food Standards Australia New Zealand. (2018). *Australia's Foodborne Illness Reduction Strategy 2018-2021+*. Food Regulation. URL: www.foodregulation.gov.au/sites/default/files/2023-09/australia-s-foodborne-illness-reduction-strategy-2018-2021.pdf (PDF, 519 KB).

Ford, L., Glass, K., Veitch, M., Wardell, R., Polkinghorne, B., Dobbins, T., Lal, A., & Kirk, M. D. (2016). Increasing Incidence of *Salmonella* in Australia, 2000–2013. *PLOS ONE*, *11*(10), e0163989. URL: doi.org/10.1371/journal.pone.0163989

Ford, L., Haywood, P., Kirk, M. D., Lancsar, E., Williamson, D. A., & Glass, K. (2019). Cost of Salmonellosiss in Australia, 2015. *Journal of Food Protection*, *82*(9), 1607–1614. URL: doi.org/10.4315/0362-028X.JFP-19-105

Ford, L., Moffatt, C. R. M., Fearnley, E., Miller, M., Gregory, J., Sloan-Gardner, T. S., Polkinghorne, B. G., Bell, R., Franklin, N., Williamson, D. A., Glass, K., & Kirk, M. D. (2018). The Epidemiology of *Salmonella* enterica Outbreaks in Australia, 2001–2016. *Frontiers in Sustainable Food Systems*, *2*. URL: doi.org/10.3389/fsufs.2018.00086

General Practice Health of the Nation. (2024). *Government contribution to care*. The Royal Australian College of General Practitioners. URL: www.racgp.org.au/health-of-the-nation/chapter-3-general-practice-viability/government-contribution-to-care

Glass, K., McLure, A., Bourke, S., Cribb, D. M., Kirk, M., March, J. C., Daughtry, B., Snezana Smiljanic, & Lancsar, E. (2023). The Cost of Foodborne Illness and Its Sequelae in Australia Circa 2019. *Foodborne Pathogens and Disease*. URL: doi.org/10.1089/fpd.2023.0015.

Hall, G., Yohannes, K., Raupach, J., Becker, N., & Kirk, M. (2008). Estimating Community Incidence of *Salmonella*, Campylobacter, and Shiga Toxin–producing Escherichia coli Infections, Australia. *Emerging Infectious Diseases*, *14*(10), 1601–1609. URL: doi.org/10.3201/eid1410.071042

Lloyd, J. (2008). *Cost of Diseases.* Animal Health Alliance. URL: animalmedicinesaustralia.org.au/wp-content/uploads/2025/03/Cost-of-Diseases-final-report-15-Dec-2008.pdf (PDF, 176 KB).

McLure, A., Shadbolt, C., Desmarchelier, P. M., Kirk, M. D., & Glass, K. (2022). Source attribution of salmonellosis by time and geography in New South Wales, Australia. *BMC Infectious Diseases*, *22*(1). URL: doi.org/10.1186/s12879-021-06950-7

National Hospital Cost Data Collection Public Sector. (2025, March 12). Independent Health and Aged Care Pricing Authority. URL: www.ihacpa.gov.au/health-care/costing/national-hospital-cost-data-collection/national-hospital-cost-data-collection-public-sector

NSW Government DPIRD. (2022). *Performance, Data and Insights: Eggs*. www.dpi.nsw.gov.au. URL: www.dpi.nsw.gov.au/about-us/publications/pdi/2022/eggs

OzFoodNet. (2022). *Enhancing Foodborne Disease Surveillance Across Australia NSW ANNUAL REPORT 2020*. (n.d.). URL: www.health.nsw.gov.au/Infectious/foodborne/Publications/nsw-ozfoodnet-annual-report-2020.pdf (PDF, 935 KB).

OzFoodNet Working Group. (2015). Monitoring the incidence and causes of diseases potentially transmitted by food in Australia: Annual report of the OzFoodNet network, 2011. *Communicable Diseases Intelligence Quarterly Report*, *39*(2), E236–264. URL: pubmed.ncbi.nlm.nih.gov/26234259/

Scott, E. A. & Australian Eggs. (2024). Overview of the egg industry in Australia. *Food Standards Australia New Zealand,* 1–31. URL: www.foodstandards.gov.au/sites/default/files/2025-03/P1060-%20SD%205%20-%20Overview%20of%20egg%20industry%20in%20Australia.pdf

Verbooy, K., Hoefman, R., van Exel, J., & Brouwer, W. (2018). Time Is Money: Investigating the Value of Leisure Time and Unpaid Work. *Value in Health*, *21*(12), 1428–1436. URL: doi.org/10.1016/j.jval.2018.04.1828

Ward, K., Franklin, N., Furlong, C., Hope, K., & Flint, J. (2015). *OzFoodNet — Enhancing Foodborne Disease Surveillance across Australia. NSW 2014 OzFoodNet Annual Report*. Retrieved March 24, 2025, from URL: www.health.nsw.gov.au/Infectious/foodborne/Publications/nsw-ofn-annual-report-2014.pdf (PDF, 764 KB).

APPENDIX

Technical notes

Technical note on the forecasting model

Monthly salmonellosis incidence rates from January 1991 to September 2016 were modelled in R using the auto.arima() function from the 'forecast' package. A seasonal frequency of 12 months was specified to account for annual seasonal patterns in salmonellosis incidence.

Model selection was automated using minimisation of the Akaike Information Criterion corrected for small sample size. The final selected model was ARIMA(1,0,0)(0,1,1)$_{12}$ with drift. This model included one non-seasonal autoregressive term, one seasonal moving average term, one seasonal differencing component at a 12-month lag and a drift term representing the long-term trend.

The fitted model can be expressed as:

$$(1-\phi_1 B)(1-B^{12})y_t = c + (1+\Theta_1 B^{12})\varepsilon_t$$

where y_t represents the monthly salmonellosis incidence rate at time t, B is the backshift operator, c is the drift term and ε_t represents random error terms. Estimated coefficients were 0.599 for the autoregressive parameter, −0.723 for the seasonal moving average parameter and 0.0115 for the drift component.

Model adequacy was assessed using residual diagnostics. Visual inspection of residual autocorrelation plots indicated no substantial remaining autocorrelation, and the Ljung-Box test showed residuals consistent with white noise (p = 0.787). These diagnostics supported the suitability of the model for forecasting purposes.

The modelling approach assumes that residual errors are independent, approximately normally distributed and exhibit constant variance over time.

Technical note on the calculation of health system costs and life impacts

Avoided health system costs and life impacts were estimated by applying morbidity impact parameters and associated unit costs to the estimated reduction in salmonellosis cases attributable to the SRS and associated vaccination activities.

The number of avoided salmonellosis cases was estimated through the evaluation forecasting approach described elsewhere in this report. Reductions in secondary conditions, including ReA and IBS, were estimated by applying average incidence probabilities from Ford *et al.* (2019) to the estimated reduction in salmonellosis cases.

Health system utilisation impacts were estimated using average treatment-seeking and medication utilisation parameters derived from Ford *et al.* (2019) Supplemental Material 1. Parameters included the proportion of cases requiring GP consultations, emergency department presentations, hospitalisation, pharmaceutical treatment and other healthcare utilisation outcomes. The parameter values documented in Supplemental Material 1 were weighted using the age distribution of salmonellosis notifications reported in NSW surveillance data to derive population-average estimates suitable for the evaluation. A summary of these age-agnostic parameter values is presented in Table 8.

Avoided health system costs were estimated using the following general approach:

$$Avoided\ cost_i = Avoided\ cases \times Probability_i \times Unit\ cost_i$$

Where:

- *Avoided cases* represents the estimated reduction in salmonellosis cases attributable to the intervention.
- *Probability$_i$* represents the likelihood of a given healthcare utilisation outcome or secondary condition occurring.
- *Unit cost$_i$* represents the estimated FY2025 cost associated with that outcome.
- For example, avoided hospitalisation costs were estimated as:

$$\begin{gathered} Avoided\ hospitalisation\ costs \\ = Avoided\ cases \times Hospitalisation\ rate \times Average\ hospitalisation\ cost \end{gathered}$$

Similarly, avoided ReA and IBS costs were estimated by multiplying avoided salmonellosis cases by the estimated incidence of each condition, the likelihood of a particular healthcare utilisation outcome and the associated treatment costs.

Unit cost estimates were obtained from a combination of published literature and Australian administrative cost sources, presented in Table 9.

Key inputs to calculate impact of salmonellosis and related morbidities

Age-weighted salmonellosis and related morbidity impact parameters

The estimates presented in Table 8 were derived from Supplemental Material 1 of Ford et al. (2019) and adjusted to reflect the age distribution of salmonellosis notifications reported in NSW in the 2019 OzFoodNet annual surveillance report. Weighting was applied using the relative proportion of salmonellosis cases by age group to produce age-agnostic estimates suitable for use in the cost-benefit analysis. The resulting parameters represent population-weighted averages across the NSW salmonellosis case profile.

Healthcare utilisation percentages represent the number of instances of care sought divided by the total number of cases.

For more information on the parameter values and how they were estimated, see Ford et al. (2019).

Table 8: Age-agnostic medical outcome utilisation and life impacts per salmonellosis case, ReA or IBS case

Cause	Variable	Low	Medium	High
Salmonella	No medical care	40%	53%	65%
Salmonella	GP visits	25%	37%	50%
Salmonella	ED visits	6.0%	12.4%	22.8%
Salmonella	Hospitalisations	2%	5%	10%
Salmonella	Days in hospital	4	4	4
Salmonella	Case fatality rate	0.00%	0.01%	0.01%
Salmonella	Antidiarrhoeal use	9%	24%	48%
Salmonella	Painkiller use	9%	27%	53%
Salmonella	Anti-nausea use	2%	11%	36%
Salmonella	Anti-cramps use	1%	8%	27%
Salmonella	Antibiotic use	1%	6%	24%
Salmonella	Stool culture/PCR (cases, median)	12%	15%	16%
Salmonella	Days lost paid work (illness)	0.4	0.7	1.3
Salmonella	Days lost paid work (caring)	0.2	0.6	1.3
Salmonella	Days lost activities (illness)	3.7	5.0	6.5
Salmonella	Days lost activities (caring)	0.8	1.3	2.2
IBS	Incidence (cases)	3.7%	6.8%	12.3%
IBS	GP visits	356%	375%	394%

IBS	ED visits	0.00%	0.00%	0.00%
IBS	Hospitalisations	4%	9%	20%
IBS	Days in hospital	2	2	2
IBS	Medications	39%	40%	42%
IBS	Stool culture	67%	100%	100%
IBS	FBC	67%	100%	100%
IBS	ESR	67%	100%	100%
IBS	LFT	67%	100%	100%
IBS	CRP	67%	100%	100%
IBS	Coeliac screening	67%	100%	100%
IBS	Radiology	65%	67%	68%
IBS	Ultrasound	48%	50%	52%
IBS	Endoscopy/biopsy	5%	9%	13%
IBS	Specialist visits	29%	30%	32%
IBS	New ongoing illness	22%	43%	66%
IBS	Days lost work/activities	1.1	1.9	2.2
IBS	Lost productivity (ongoing)	1.7	3.6	6.8
ReA	Incidence (cases)	1.33%	5.55%	14.68%
ReA	GP visits	66%	80%	89%
ReA	ED visits	0.00%	0.00%	0.00%
ReA	Hospitalisations	0%	1%	2%
ReA	Days in hospital	3.2	3.2	3.2
ReA	Antibiotics	16%	20%	24%
ReA	NSAID	53%	76%	92%
ReA	Eye drops	16%	20%	24%
ReA	Prednisone	0%	2%	10%
ReA	Inter-articular glucocorticoid	16%	20%	24%

ReA	DMARD	1%	10%	30%
ReA	Joint aspiration	16%	20%	24%
ReA	Stool culture	10%	13%	17%
ReA	Serology	10%	13%	17%
ReA	Urine culture	10%	13%	17%
ReA	CRP & Urate	16%	20%	24%
ReA	FBC, ESR	16%	20%	24%
ReA	Rheumatoid factor	16%	20%	24%
ReA	Renal function	16%	20%	24%
ReA	HLA-B27	16%	20%	24%
ReA	X-ray	1%	10%	30%
ReA	Ultrasound	2%	3%	6%
ReA	MRI	0%	1%	3%
ReA	Specialist referral	16%	20%	24%
ReA	Specialist visits	22%	24%	26%
ReA	New ongoing illness	23%	50%	77%
ReA	Days lost activities	18.5	20.2	21.9
ReA	Days lost paid work	2.6	3.4	4.3

Costs associated with disease-related impacts

Table 9 summarises the cost values used to calculate the avoided health and life impacts. Where costs are not included in the below table, they feature in Table 3.

All costs were adjusted to factor in inflation from 2014 to 2025. The Treasury Outcomes Value Database consumer and medical price indices were used for this purpose.

For more information on the parameter values and how they were estimated, see the listed source and associated notes.

Table 9: Estimated average cost of health and life impacts

Cause	Outcome	Cost (2025)	Source and notes
Salmonella	GP visits	$87.49	General Practice Health of the Nation (2024).

Salmonella	ED visit	$730.34	Ford et al. 2019
Salmonella	Hospitalisations	$9,072.98	National Hospital Cost Data Collection (2025). Daily cost multiplied by average number of days in hospital.
Salmonella	Deaths	$5,863,082.21	NSW Treasury Outcome Values Database (2024), internal resource.
Salmonella	Antidiarrhoeal use	$15.12	Ford et al. 2019
Salmonella	Painkiller use	$13.06	Ford et al. 2019
Salmonella	Anti-nausea use	$20.16	Ford et al. 2019
Salmonella	Anti-cramps use	$22.47	Ford et al. 2019
Salmonella	Antibiotic use	$14.81	Ford et al. 2019
Salmonella	Stool culture/PCR (cases, median)	$58.92	Ford et al. 2019
Salmonella	Day lost paid work	$410.40	ABS (2025) Average Weekly Earnings.
Salmonella	Day lost activities	$134.70	Verbooy et al. (2018) estimate for willingness to accept an hour less leisure multiplied by average hours of leisure per day.
IBS	GP visits	$87.49	General Practice Health of the Nation (2024).
IBS	ED visit	$730.34	Ford et al. 2019
IBS	Hospitalisations	$4,483.60	National Hospital Cost Data Collection (2025). Daily cost multiplied by average number of days in hospital.
IBS	Medications	$35.41	Ford et al. 2019. Assumed half of relevant medications were purchased.
IBS	Stool culture	$58.92	Ford et al. 2019
IBS	FBC	$18.42	Ford et al. 2019
IBS	ESR	$8.55	Ford et al. 2019
IBS	LFT	$19.23	Ford et al. 2019
IBS	CRP	$10.65	Ford et al. 2019
IBS	Coeliac screening	$27.54	Ford et al. 2019
IBS	Radiology	$41.20	Ford et al. 2019

IBS	Ultrasound	$134.81	Ford et al. 2019
IBS	Endoscopy/biopsy	$194.37	Ford et al. 2019
IBS	Specialist visits	$230.88	Ford et al. 2019 reports out-of-pocket costs only. Estimated total costs were derived by incorporating government contributions, assumed to be approximately the same as the patient out-of-pocket component.
IBS	Days lost work/activities	$434.94	Calculated weighted average day (work/activities) because a split of work/activities lost was not provided in Ford et al. 2019. $\text{Daily weighted cost} = \text{Average daily wage x } \frac{5}{7} + \text{Willingness to pay for a day's leisure}$
ReA	GP visits	$87.49	General Practice Health of the Nation (2024).
ReA	ED visits	$730.34	Ford et al. 2019
ReA	Hospitalisations	$7,575.83	National Hospital Cost Data Collection (2025). Daily cost multiplied by average number of days in hospital.
ReA	Antibiotics	$14.81	Ford et al. 2019
ReA	NSAID	$13.69	Ford et al. 2019
ReA	Eye drops	$11.72	Ford et al. 2019
ReA	Prednisone	$9.62	Ford et al. 2019
ReA	Inter-articular glucocorticoid	$27.05	Ford et al. 2019
ReA	DMARD	$114.28	Ford et al. 2019
ReA	Joint aspiration	$99.09	Ford et al. 2019
ReA	Stool culture	$58.92	Ford et al. 2019
ReA	Serology	$61.66	Ford et al. 2019
ReA	Urine culture	$22.67	Ford et al. 2019
ReA	CRP & Urate	$12.86	Ford et al. 2019
ReA	FBC, ESR	$13.49	Ford et al. 2019

ReA	Rheumatoid factor	$12.52	Ford et al. 2019
ReA	Renal function	$93.77	Ford et al. 2019
ReA	HLA-B27	$45.13	Ford et al. 2019
ReA	X-ray	$99.07	Ford et al. 2019
ReA	Ultrasound	$101.75	Ford et al. 2019
ReA	MRI	$496.01	Ford et al. 2019
ReA	Specialist visits	$230.88	Ford et al. 2019 reports out-of-pocket costs only. Estimated total costs were derived by incorporating government contributions, assumed to be approximately the same as the patient out-of-pocket component.
ReA	Days lost activities	$134.70	ABS (2025) Average Weekly Earnings.
ReA	Days lost paid work	$410.40	Verbooy et al. (2018) estimate for willingness to accept an hour less leisure multiplied by average hours of leisure per day.