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Canada

Evaluation of the Public Health Agency of Canada's Food-borne and Water-borne Enteric Illness Activities 2012-17

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Office of Audit and Evaluation
Health Canada and the Public Health Agency of Canada

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List of Acronyms

AERO	All Events Response Operations Platform
CARSS	Canadian Antimicrobial Resistance Surveillance System
CFEZID	Centre for Food-borne, Environmental and Zoonotic Infectious Diseases
CFIA	Canadian Food Inspection Agency
CIPARS	Canadian Integrated Program for Antimicrobial Resistance
ECSTR	E. coli In-Silico Typing Resource
FIORP	Food-borne Illness Outbreak Response Protocol
HSIB	Health Security Infrastructure Branch
IRIDA	Integrated Rapid Infectious Diseases Analysis Project
IT	Information Technology
MLVA	Multiple-Locus Variable number tandem repeat Analysis
NESP	National Enteric Surveillance Program
NML	National Microbiology Laboratory
OICC	Outbreak Investigation Coordinating Committee
PFGE	Pulsed-field Gel Electrophoresis
PHAC	Public Health Agency of Canada
SISTR	Salmonella In-Silico Typing Resource
US CDC	United States Centres for Disease Control and Prevention

Executive Summary

This report presents the findings of the evaluation of the Public Health Agency of Canada's (PHAC) food/water-borne enteric illness activities.

Evaluation Purpose and Scope

The purpose of the evaluation was to assess the performance of PHAC's food/water-borne enteric illness activities for the period of January 2012 to October 2017. Those activities are mainly delivered through the Centre for Food-borne, Environmental and Zoonotic Infectious Diseases (CFEZID), as well as the National Microbiology Laboratory (NML). During the evaluation period, the Health Security Infrastructure Branch (HSIB) also received funding following through the response to the 2008 Listeriosis outbreak to undertake public health capacity building activities in relation with response to food-borne outbreaks.

The previous evaluation of PHAC's activities in this area determined an ongoing need and role for the Government of Canada to contribute to Canada's food safety system in its current capacity. As a result, the evaluation that follows is based on a review of the program areas' performance, with a particular focus on three key areas:

- Whole Genome Sequencing;
- Public communications related to food/water-borne outbreaks; and,
- Public health capacity built through food-borne response funding provided after the 2008 listeriosis outbreak for PHAC activities outside of CFEZID and the NML.

The evaluation also explores PHAC's work in the area of antimicrobial resistance and its link to the food supply, through its management of the Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS).

Program Description

PHAC shares the federal mandate with Health Portfolio partners at Health Canada and the Canadian Food Inspection Agency (CFIA) to prevent, detect, and respond to multijurisdictional outbreaks of foodborne illness.

PHAC's food/water-borne illness prevention, detection and response activities include:

- Expertise, training, and services for provincial partners and other stakeholder groups;
- National surveillance of pathogens which cause enteric illness in food and water, as well as surveillance of antimicrobial use and resistance across the food chain, through programs such as FoodNet Canada, PulseNet Canada, the National Enteric Surveillance Program, and CIPARS;
- Laboratory services and analysis of food-borne pathogens; and,
- Coordination and conducting of investigations targeted at identifying the source of a food-borne illness outbreak occurring in more than one province.

The goals of these activities are twofold: firstly, they aim to ensure that stakeholders take informed actions to prevent and respond to food/water-borne enteric disease risks, and that Canadians take informed action to protect themselves from the same risks. Secondly, they aim to ensure that scientific evidence informs food/water-borne enteric illness practices, decisions, and actions.

Conclusions

Achievement of Expected Outcomes (Effectiveness)

PHAC contributes to Canada's strong food safety system by providing surveillance capabilities, genomics bioinformatics technology, and outbreak responses. Evaluation findings provide evidence of PHAC's contributions to informing food safety interventions as well as detecting and responding to food/water-borne enteric illness outbreaks.

Overall, stakeholders found the program areas' expertise to be beneficial in helping build their own capacity through skills development, resource support, increased access to surveillance information, and assistance with source attribution during outbreaks. There were some challenges identified in regards to how information and tools are presented and shared with stakeholders

PHAC has also led and supported provinces in the transition to Whole Genome Sequencing, allowing for more detailed pathogen analysis. However, the transition is facing capacity challenges as Whole Genome Sequencing generates an exponentially higher amount of data to assess. To date, this has resulted in the identification of more food-borne enteric illness outbreaks, with no additional allocation of laboratory and epidemiological resources at both PHAC and provincial levels.

Despite the current resource constraints resulting from the impact of Whole Genome Sequencing implementation, PHAC consistently responds to the majority of outbreak notifications within 24 hours. Furthermore, all internal and external key informants perceived the Food-borne Illness Outbreak Response Protocol (FIORP) as a best practice for federal, provincial, and territorial response guidelines and frameworks.

There are opportunities to improve consistency in public communications from Health Portfolio partners during a food-borne illness outbreak. A recent communications approach has been implemented to help address inconsistent messaging that, in the past, has led to confusion among industry and the public as to the severity of the risks associated with outbreaks in progress.

Program Spending

PHAC receives ongoing funding for food/water-borne enteric illness activities delivered through the National Microbiology Laboratory (NML), and the Centre for Food-borne, Environmental and Zoonotic Infectious Diseases (CFEZID). As well, the Health Security Infrastructure Branch (HSIB) of PHAC receives funding to improve core competencies for epidemiologists, and improve surge capacity, through the development of the All Events Response Operations Platform (AERO) platform. Over the 2012-13 to 2016-17 period covered by the evaluation, the expenditures from each of the three areas totaled the following: $50M for NML, $34.3M for CFEZID, and $2.3M for HSIB.

On average, all three areas delivered their activities within budget during the evaluation period. NML's expenditures accounted for approximately 90% of their planned budget while CFEZID expenditures accounted for approximately 85% of their planned budget, and HSIB spent approximately 94% of their budget.

The implementation of Whole Genome Sequencing, which started in 2017, has increased the demand on PHAC resources, but it is too early to see this effect in the financial data examined for this evaluation.

Recommendations

The findings from this evaluation of PHAC's food/water-borne enteric illness activities have resulted in the following four recommendations.

Recommendation 1

PHAC should update its plan for the Whole Genome Sequencing implementation, taking into consideration the capacity constraints experienced in the initial phase of the transition within both PHAC and the provinces.

In light of provincial capacity constraints and the additional demand that the transition to Whole Genome Sequencing has put on PHAC's resources (e.g., human, financial, technological), PHAC should revisit its implementation planning to reflect realistic timelines and the resources needed to support a continued roll-out of this new technology. A full implementation of Whole Genome Sequencing will allow PHAC to align itself with international pathogen testing standards. As well, compared to other conventional methods, Whole Genome Sequencing provides a greater degree of precision on pathogen characteristics, which can improve the identification of contaminated food sources and potentially lead to faster resolution of outbreaks.

Recommendation 2

Improve access of upstream surveillance information and ensure the content of upstream information products is adapted to the needs of stakeholders.

PHAC should improve how it shares upstream surveillance information with stakeholders, and tailor the content of such information products to address their needs. Overall, improvements made should aim to ensure that stakeholders have a timely access to the upstream surveillance information they need to carry out their work. As part of this effort, PHAC could also examine options to better document how its upstream prevention data is used to support policy change.

Recommendation 3

Monitor the effectiveness of CFIA and PHAC's new coordinated communications process for outbreak investigations.

CFIA and PHAC have made efforts to remedy inconsistent public communications during food-borne outbreaks by embarking on a new coordinated communications approach. In light of its recent implementation, the evaluation was unable to assess the extent of its impact, although, anecdotally, key informants were complimentary of the new approach. Nevertheless, PHAC should continue to monitor the effectiveness of the newly implemented coordinated communications approach between PHAC and CFIA for outbreak communications, in order to ensure public messaging is consistent, clear, and accessible, as well as easily linked and navigable between the two Agencies' websites.

Recommendation 4

Explore how PHAC could support messaging to Canadians on food/water-borne illness prevention.

There is a need to communicate better with Canadians regarding the prevention of food-borne illness, as 1 in 10 Canadians continue to use practices that put them at risk of contracting food-borne illness. Although PHAC's role related to food/water-borne illness prevention is specific to messaging during an outbreak, and Health Canada is the primary Health Portfolio partner that communicates to Canadians outside of an outbreak, PHAC should still examine how it can support other Health Portfolio partners in improving messaging to Canadians on food/water-borne enteric illness prevention. With that in mind, it is recommended that PHAC build off of their commitment, as outlined in the 2013-2018 Food Safety Strategic Plan, to proactively engage the Canadian public and stakeholders in a more coordinated Health Portfolio approach to food-borne illness prevention.[1]

Management Response and Action Plan
Evaluation of PHAC's
Food-borne and Water-borne Enteric Illness Activities 2012 - 2017

Recommendations	Response	Action Plan	Deliverables	Expected Completion Date	Accountability	Resources
Recommendation as stated in the evaluation report	Identify whether program management agrees, agrees with conditions, or disagrees with the recommendation, and why	Identify what action(s) program management will take to address the recommendation	Identify key deliverables	Identify timeline for implementation of each deliverable	Identify Senior Management and Executive (DG and ADM level) accountable for the implementation of each deliverable	Describe the human and/or financial resources required to complete recommendation, including the source of resources (additional vs. existing budget)
The Agency should revise its Whole Genome Sequencing (WGS) implementation plan, accounting for capacity constraints experienced within the initial phase of implementation.	Agree	Building on the PulseNet Canada Genomics Roadmap, PHAC will assess critical capacity gaps impeding the adoption of genome sequencing. PHAC will explore resourcing options and strategic engagement of partners to address the gaps identified. 1. Develop a 'gap assessment' to identify critical laboratory and epidemiological capacity constraints for genome sequencing implementation	*(1) Gap Assessment* a. Engagement of P/T partners to identify gaps and barriers b. Review of current status in comparison to desired state c. Summarize gaps and potential solutions d. Review internally and with appropriate partners e. Final Genome sequencing gap assessment	*(1) Gap Assessment* a. Formal engagement December 2017 (completed) b. December 2017 (completed) c. June 2018 d. September 2018 e. December 2018	Vice President, Infectious Diseases Prevention and Control Director General, National Microbiology Laboratory (lead) Director General, Centre for Foodborne Environmental and Zoonotic Infectious Diseases	Development of plans to be completed using existing resources. *Note: full implementation may require additional resources (to be identified upon gap assessment)

Recommendations	Response	Action Plan	Deliverables	Expected Completion Date	Accountability	Resources
Recommendation as stated in the evaluation report	Identify whether program management agrees, agrees with conditions, or disagrees with the recommendation, and why	Identify what action(s) program management will take to address the recommendation	Identify key deliverables	Identify timeline for implementation of each deliverable	Identify Senior Management and Executive (DG and ADM level) accountable for the implementation of each deliverable	Describe the human and/or financial resources required to complete recommendation, including the source of resources (additional vs. existing budget)
		2. Develop an implementation strategy in consultation with stakeholders that builds on the Genomics Roadmap and incorporates the gaps identified for fully adopting genome sequencing in PulseNet Canada laboratories and surveillance programs.	*(2) Implementation strategy* a. Development of resource plan to overcome gaps/barriers identified in the Gap Assessment b. Development of implementation plan document c. Review internally and with appropriate partners d. Final Implementation Strategy.	*(2) Implementation strategy* a. April 2019 b. August 2019 c. October 2019 d. December 2019		
Improve the suitability of how information is presented and shared with target audiences.	Agree	1. With support from PHAC Communications, review opportunities (such as practices of other federal departments) to improve methods to reach target audiences to share information	a. Environmental scan undertaken to determine how other science-based departments share information with defined target audiences.	a. September 2018	Vice President, Infectious Diseases Prevention and Control Director General, Centre for Foodborne	Existing resources.

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Recommendation as stated in the evaluation report	Identify whether program management agrees, agrees with conditions, or disagrees with the recommendation, and why	Identify what action(s) program management will take to address the recommendation	Identify key deliverables	Identify timeline for implementation of each deliverable	Identify Senior Management and Executive (DG and ADM level) accountable for the implementation of each deliverable	Describe the human and/or financial resources required to complete recommendation, including the source of resources (additional vs. existing budget)
		such as scientific reference material and relevant findings from surveillance and outbreak response programs 2. Develop and implement new knowledge translation (KT) strategy with audience specific information products targeted to stakeholders and Canadians. 3. Develop a monitoring framework on how the KT strategy is performing.	b. Assess feasibility of adopting or implementing similar systems within PHAC; report on findings. c. KT strategy developed d. Monitoring framework developed e. KT strategy implemented	b. October 2018 c. February 2019 d. March 2019 e. April 2019	Environmental and Zoonotic Assistant Deputy Minister, Communications and Public Affairs Branch (support) Director General, Public Health Strategic Communications Directorate (support)	
Monitor the effectiveness of CFIA/PHAC's new coordinated communications approach to outbreak	Agree	1. As part of the lessons learned, revise SOP for partner Outbreak Investigation Coordinating Committee (OICC) post-outbreak debrief to include	a. First iteration of the SOP for Hot Wash lessons learned process completed	a. March 2018	Vice President, Infectious Diseases Prevention and Control Director General, Centre for	Existing resources

Recommendations	Response	Action Plan	Deliverables	Expected Completion Date	Accountability	Resources
Recommendation as stated in the evaluation report	Identify whether program management agrees, agrees with conditions, or disagrees with the recommendation, and why	Identify what action(s) program management will take to address the recommendation	Identify key deliverables	Identify timeline for implementation of each deliverable	Identify Senior Management and Executive (DG and ADM level) accountable for the implementation of each deliverable	Describe the human and/or financial resources required to complete recommendation, including the source of resources (additional vs. existing budget)
investigations.		questions about the consistency and effectiveness of coordinated messaging.			Foodborne Environmental and Zoonotic Infectious Diseases (lead), with participation from Communications.	
Explore how PHAC could support messaging to Canadians on food/water-borne illness prevention.	Agree	1. PHAC will clarify its role and contribution to the portfolio approach regarding the management of food safety messaging in order to prevent human illness from food-borne pathogens. 2. PHAC will draft an inventory/umbrella strategy of engagement activities across PHAC, working with Health Canada and CFIA to identify gaps and opportunities for increased outreach.	a. Review of current evidence related to the uptake of food safety messaging for different audiences (what works and what doesn't) b. Comprehensive environmental scan of existing health portfolio activities and communicated roles in food safety c. Develop a gap analysis report that identifies target areas for additional messaging support	a. April 2018 b. July 2018 c. October 2018	Vice President, Infectious Diseases Prevention and Control Director General, Centre for Foodborne Environmental and Zoonotic Infectious Diseases (lead) Assistant Deputy Minister, Communications and Public Affairs Branch (support) Director General, Public Health Strategic Communications Directorate (support)	Existing resources. *Note: full implementation of framework may require additional resources.

Recommendations	Response	Action Plan	Deliverables	Expected Completion Date	Accountability	Resources
Recommendation as stated in the evaluation report	Identify whether program management agrees, agrees with conditions, or disagrees with the recommendation, and why	Identify what action(s) program management will take to address the recommendation	Identify key deliverables	Identify timeline for implementation of each deliverable	Identify Senior Management and Executive (DG and ADM level) accountable for the implementation of each deliverable	Describe the human and/or financial resources required to complete recommendation, including the source of resources (additional vs. existing budget)
			d. Consultation report that identifies internal and external opportunities for increasing reach of messaging e. Host focussed health portfolio meetings and/or workshop to draft a strategic framework for advancing messaging to Canadians on food/water-borne illness prevention f. Health portfolio approved strategic framework	d. March 2019 e. September 2019 f. November 2019	**Support to address this particular recommendation will also be sought from relevant areas of Health Canada and the Canadian Food Inspection Agency.	

1.0 Evaluation Purpose

The purpose of the evaluation was to assess the performance of the Public Health Agency of Canada's (PHAC) food/water-borne enteric illness activities for the period of January 2012 to October 2017.

2.0 Program Description

2.1 Program Context

Every year, four million individuals living in Canada are affected by food-borne illness, resulting in 11,600 hospitalizations and 238 deaths.[2] These illnesses are typically concentrated in the stomach and/or intestinal tract, and present themselves in humans with symptoms like nausea, vomiting, abdominal cramps, and diarrhoea. Food-borne pathogens[1] can also cause systemic and invasive infectious diseases.

Food/water-borne illnesses are diseases caused by the ingestion of food or water contaminated by bacteria, viruses, parasites, chemicals, or bio-toxins (poisonous substances). Contamination can occur, and be mitigated, at multiple points along the farm-to-fork continuum (e.g., farming, production, food preparation). The most common causes of food-borne enteric illness are bacteria such as *E. coli*, *Listeria*, *Campylobacter*, *Salmonella*, and *Shigella*.

As well, antimicrobial resistance can be transmitted through the food chain, due to the potential development and spread of resistant bacteria that can be transferred to humans through the food chain and direct contact. This has long-term impacts on human health, as evidenced by some of the population developing resistant and serious infections that cannot be treated by available antimicrobials.[3]

An outbreak of food/water-borne enteric illness is an incident in which two or more persons experience similar illnesses after a common source exposure. An outbreak is identified through laboratory surveillance, or by observing an increase in illness that is unusual in terms of time or geography. An outbreak is confirmed through laboratory and/or epidemiological evidence.[4]

[1] A pathogen is anything that can produce disease (e.g., a virus, fungi, or bacteria).

2.2 Program Profile

PHAC's delivers food/water-borne enteric illness activities through the Centre for Food-borne, Environmental and Zoonotic Infectious Diseases (CFEZID) and the National Microbiology Laboratory (NML).

CFEZID's activities focus on prevention, detection, and response by way of:

- conducting national surveillance for enteric illnesses and antimicrobial resistance and use along the food chain;
- detecting and responding to food-borne disease outbreaks;
- tracking illness and identifying risks to inform upstream prevention;
- providing consultations, content expertise, coordination and leadership in multijurisdictional outbreak investigations and in support of surveillance and stewardship;
- interpreting and commenting on the strength of evidence collected during the epidemiological investigations of food-borne illness outbreaks;
- providing training in outbreak response and investigation methods;
- coordinating and collaborating with international surveillance authorities; and
- managing the Public Health Alerts: Enteric Alerts system.[5]

These activities are intended to ensure that stakeholders take informed actions to prevent and respond to food and water-borne enteric disease risks, and that Canadians take informed action to protect themselves from the same infectious disease risks. The long-term outcome of the Centre's food/water-borne enteric illness activities is that Canadians are protected from infectious diseases that rise from food, the environment and animals.[2]

The NML provides:

- national reference laboratory services;
- laboratory analyses for real-time surveillance and outbreak response systems;
- bioinformatic and scientific computing infrastructure on which the above activities are based;
- methods development targeted at improving detection and analysis capabilities (e.g., more efficient, effective, and economical approaches), and their ability to more precisely identify pathogens for clustering, potentially contributing to source attribution; and
- risk modelling, knowledge synthesis and decision analysis.

[2] For more detail on the program narrative for CFEZID, refer to Appendix 1

The NML's activities in this area are intended to ensure that laboratory science evidence informs food/water-borne enteric illness practices, decisions, and actions. This is expected to result in the long-term outcome of Canada having the national system and science needed to anticipate and respond to infectious disease threats.[3]

PHAC is just one of many players in the overall Canadian food safety system, which also includes local authorities, provincial and territorial governments, and other Government of Canada organizations. These partners contribute to national food safety in the following ways:

- Local/ regional level: Responsible for investigating food establishments and following up on human illnesses resulting from contaminated food and water within their jurisdiction. This also includes reporting food-borne pathogens and human illness cases to provincial and territorial officials. During regular operating periods (i.e., outside of an outbreak), local public health units also conduct surveillance, as well as epidemiological and food safety investigations.

- Provinces and Territories: Responsible for inspecting and licensing some of the provinces' and territories' food producers and distributers within their region, which includes production, processing, and distribution facilities, retail stores, and restaurants. Provinces and territories also conduct ongoing food-borne illness surveillance and perform laboratory testing of food and clinical samples within their jurisdiction.[4] In the event of an outbreak that has affected more than one health region in their province or territory, they are responsible for leading the related epidemiological and food safety investigations.

- Health Canada: Responsible for working with governments, industry, and consumers to establish policies, and set standards and regulations related to safety and nutritional quality of all food sold in Canada.[6] The Department also provides advice and is responsible for food safety messaging and resources outside of a food-borne illness outbreak.

- CFIA: Responsible for conducting ongoing monitoring and inspection of food products, and enforcing the food safety policies and standards set out by Health Canada.[7] In the event of an outbreak, they conduct food safety investigations, including product recalls.

- Agriculture and Agri-Food Canada: Supports activities targeted at farmers and consumers through all phases of production, processing, and marketing of food products.

[3] For more detail on the program narrative for the Laboratory Science Leadership program, refer to Appendix 2.
[4] Territories do not have public health laboratories, and instead have arrangements in place with neighbouring provinces to complete necessary testing.

2.3 Program Resources

PHAC receives funding for food/water-borne enteric illness activities delivered through the National Microbiology Laboratory (NML), and the Centre for Food-borne, Environmental and Zoonotic Infectious Diseases (CFEZID). The Health Security Infrastructure Branch (HSIB) also received funding to improve core competencies for epidemiologists and improve surge capacity through the development of the All Events Response Operations (AERO) platform.

Over the 2012-13 to 2016-17 period, the budget allocated to each of the three areas totaled the following: $55.5M for NML, $40.4M for CFEZID, and $2.4M for HSIB.

3.0 Evaluation Description

3.1 Evaluation Scope, Approach and Design

The scope of the evaluation covered the period of January 2012 to October 2017 for PHAC's food and water-borne enteric illness activities. The previous evaluation of PHAC's activities in this area determined there is an ongoing need and role for the Government of Canada to contribute to Canada's food safety system in its current capacity. As a result, the evaluation that follows is based on a review of the program areas' performance, with a particular focus on three key areas:

- Whole Genome Sequencing;
- Public communications related to food/water-borne outbreaks; and,
- Public health capacity built through food-borne response funding provided after the 2008 listeriosis outbreak for activities outside of CFEZID and NML within PHAC.

The evaluation also explores PHAC's work in the area of antimicrobial resistance, and its link to the food supply, through its management of the Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS).

The evaluation is consistent with the Treasury Board's *Policy on Results* (2016). Data for the evaluation was collected using various methods, including a document review, a file and condensed literature review, a review of financial and performance measurement data, as well as external and internal key informant interviews. A total of 41 interviews were conducted. Of these, 26 were with PHAC staff within and beyond the program area. The remaining 15 interviews were conducted with external stakeholders. The use of multiple lines of evidence and triangulation were intended to increase the reliability and credibility of the evaluation findings and conclusions.

The evaluation did not examine activities related to environmental and zoonotic infectious diseases, as these activities were covered under previous evaluations.

3.2 Limitations and Mitigation Strategies

The following table outlines the limitations encountered during the implementation of the selected methods for this evaluation. Also noted are the mitigation strategies put in place to ensure that the evaluation findings can be used with confidence to guide program planning and decision-making.

Table 1: Limitations and Mitigation Strategies

Limitation	Impact	Mitigation Strategy
Whole Genome Sequencing output data is preliminary, and actual impacts and trends will not be known until at least one year's worth of data has been collected and analyzed.	Unable to highlight the full extent of the impact of introducing Whole Genome Sequencing as a laboratory method for detecting food-borne illnesses in Canada.	Used data on the activation rates for the Outbreak Investigation Coordinating Committee (OICC) to highlight the residual impact since the implementation of Whole Genome Sequencing.
Limited representation of industries in key informant interviews.	Limited firsthand information available to draw conclusions about the impact and suitability of program activities as they relate to industry partners.	Triangulated internal key informant statements by consulting industry websites and webinars in order to assess uptake of food-borne illness messaging.
Some key performance indicators were updated or changed during the period under evaluation.	Not always able to establish certain performance trends throughout the entire period under review due to the discontinuation or introduction of indicators at a midway point.	Used performance data resulting from previous indicators, where available, and complemented this information with data from the most recent indicators.

4.0 Findings

4.1 Information and Tools for Stakeholders to Prevent, Detect and Respond to Food/Water-borne Illnesses

4.1.1 Expertise

Internal and external key informants frequently spoke to the value and importance of the strong collaborative relationship between PHAC's food/water-borne enteric illness teams and their stakeholders. Health Portfolio, provincial, and local stakeholders were highly complimentary of PHAC's food/water-borne illness staff, indicating that their ongoing relationship with PHAC allows them to easily make information requests as needed. Client surveys and interviews affirmed the timeliness and accessibility of PHAC's staff in providing advice and responding to questions. Furthermore, the evaluation found evidence of information sharing and network development with international partners. In addition, PHAC exchanges information and best practices with international public health partners, contributing to a greater knowledge base for outbreak detection and response. This has included participation in such international partnerships as: the World Health Organization's Food-borne Disease Burden Epidemiology Reference Group, the World Health Organization's Codex Alimentarius Commission[8,5], and the Pan-American Health Organization's food-borne diseases and antimicrobial resistance/use surveillance.

PHAC produces and provides reliable and well-respected food/water-borne enteric illness resources and expertise in the areas of reference services, surveillance and research, tool and methods development, as well as training to support detection and outbreak response.

4.1.2 Upstream Prevention

PHAC conducts upstream prevention activities through the coordination of surveillance systems designed to identify trends and sources of illnesses, as well as potentially influence policy. These two systems, described below, rely on both active (e.g., samples collected by the program) and passive (e.g., data provided to the program) surveillance methods (see Appendix 3). The data from both systems has been integrated, to the degree possible, to provide a more fulsome information base to inform upstream prevention.

FoodNet Canada surveillance provides information on areas of concern and strength vis-à-vis food safety, within the full farm to fork continuum (human, retail, food farm, and local water). FoodNet Canada's primary objectives are to identify significant risk factors for enteric illness, determine which foods are making Canadians ill, track disease rates over time, and contribute information resources on prevention that can be used to inform policy and other actions.[9]

Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS) generates, collects, and collates data examining antimicrobials used in animals (sales data and farm level reporting), and the distribution of antimicrobial resistance throughout the food chain (farm, slaughter, and retail), to assess the impact on human health.

The evaluation found some evidence of the usefulness of PHAC's work, supported by examples of use at the federal and provincial levels. A small sample client survey administered by the program indicates that 94% of respondents (n=17) found that the FoodNet Canada Short Report contributed to enteric disease knowledge surveillance.

[5] The Codex Alimentarius Commission develops international food standards, with the goal of protecting consumer health and facilitating fair trade practices in the food industry.

Many provincial and Health Portfolio stakeholders identified using FoodNet Canada data to inform risk assessments and the ranking of risks associated with given combinations of food and pathogens[10], citing that the integration of different sources (e.g., retail, farm) captures a greater range of considerations to inform analyses.

Many external key informants also indicated using FoodNet Canada data, in collaboration with other sources, to better inform resource allocation and the determining of priorities at the provincial level. Other PHAC sources that have contributed to informing Health Portfolio partners' and provincial authorities' risk and priority planning include:

- **FoodBook:** PHAC's FoodBook study (2015) provides data on how frequently Canadians are eating certain types of food, which helps provide context for food-borne illness risk modelling.[11] CFIA in particular identified using PHAC's risk assessment work to help understand the root causes of certain food-borne illnesses, and as a result shaped some of their considerations in how they prioritize their resource allocation.
- **PHAC's risk work:** PHAC's Risk and Information Synthesis of Knowledge team develops risk assessment tools for analyzing data generated through enhanced and integrated food and human illness surveillance, which can serve as an additional information source for consideration when developing guidance around interventions to prevent food-borne illness.

CIPARS data was also identified as being useful to support discussions on potential interventions that could be pursued in order to reduce risk. As highlighted in PHAC's previous food-borne enteric illness evaluation[12], poultry industry representatives consulted CIPARS data to inform the introduction of a temporary voluntary ban on the use of certain antibiotics. Since then, the data have continued to be used to support industry interventions on the use of medically important antimicrobials in animals. Data illustrates the development of antimicrobial-resistant Salmonella moving through the food chain and into humans, and identifies drops in rates of resistance in retail chickens and in humans after introducing an intervention. As of May 15, 2014, the Chicken Farmers of Canada, in collaboration with multiple producers, independently implemented a ban on the preventative use of Category I (strongest importance to human health) antimicrobials in the chicken sector. They also announced the elimination of preventative use Category II antibiotics by the end of 2018, and Category III antibiotics by the end of 2020.

External key informants commonly indicated that PHAC's surveillance systems are a reputable source of information. However, program staff indicated that policy uptake is challenging to assess, since PHAC does not thoroughly track how stakeholders have used their information products. Key informants highlighted other limitations specific to coverage the accessibility of the information, including posting delays, and the format and media used to distribute information.

Coverage

A program-led data quality assessment of FoodNet Canada surveillance systems reported that operating with three sentinel sites instead of the intended five[6] has caused limitations in the generalizability of the data collected.[13] In particular, the coverage of sentinel sites has not yet met the technical criteria for 'national coverage', which requires having sentinel sites operating in catchment areas that, when combined, account for 10% of the Canadian population. A few internal and external key informants indicated that comprehensive national data from five sentinel sites could improve the rigour and utility of data for regulators, other partners, and policy-makers.

Between 2012 and 2014, two sentinel sites were operational in Ontario and British Columbia. FoodNet Canada implemented a third sentinel site in Alberta, beginning in 2014. Program respondents have indicated that discussions were underway to expand FoodNet Canada to a fourth sentinel site in Quebec, though the site was not yet active in the time period of this evaluation. From 2012 to 2015,[7] there were some gaps in data coverage of particular FoodNet Canada components. In 2012, only Ontario was conducting farm sampling and in 2014, two of three provinces were sampling water. By 2015, with a few exceptions,[8] annual reporting within each sentinel site had grown to include all four FoodNet Canada components (see Table 2).

[6] PHAC's Technical Advisory Committee had determined that FoodNet Canada would require five sentinel sites in order for its surveillance data to be considered nationally representative.
[7] FoodNet Canada annual reports were not available for 2016 and 2017.
[8] During the 2015 avian flu outbreak, Ontario's FoodNet Canada sampling was limited beginning in August, and British Columbia experienced the same challenges at the start of September that same year.

Table 2: FoodNet Canada Components by Province

Components by Province		Surveillance Data 2012[a]	2013[b]	2014[c]	2015[d]
Retail Surveillance	Ontario	x	x	x	x
	British Columbia	x	x	x	x
	Alberta			x[9]	x
Farm Surveillance	Ontario	x	x	x[10]	x[11]
	British Columbia	n/a	x	x	x[12]
	Alberta			x	x
Water Surveillance	Ontario	x[13]	x[14]	n/a	x
	British Columbia	x[15]	x[16]	x[17]	x
	Alberta			x	x
Human Surveillance	Ontario	x	x	x[18]	x
	British Columbia	x	X	x	x
	Alberta			x	x

[a] PHAC. (2014). *FoodNet Canada Annual Report 2012*. Retrieved from: http://publications.gc.ca/collections/collection_2014/aspc-phac/HP37-17-1-2012-eng.pdf
[b] PHAC. (2014). *FoodNet Canada Annual Report 2013*. Retrieved from: http://publications.gc.ca/collections/collection_2014/aspc-phac/HP37-17-1-2013-eng.pdf
[c] PHAC. (2015). *FoodNet Canada Annual Report 2014*. Retrieved from: http://publications.gc.ca/collections/collection_2016/aspc-phac/HP37-17-1-2014-eng.pdf
[d] PHAC. (2017). *FoodNet Canada Annual Report 2015.* Retrieved from: http://publications.gc.ca/collections/collection_2017/aspc-phac/HP37-17-1-2015-eng.pdf

The sentinel site approach used by active surveillance systems such as the FoodNet program in Canada and the United States[14] has benefits for upstream prevention of food/water-borne illness outbreaks. Sentinel sites are able to detect cases of food-borne illness that are not linked to an outbreak, referred to as "sporadic illnesses". Sporadic illnesses are more common than outbreaks, and are usually less likely to be investigated.[15] Furthermore, the detailed information collected at sentinel sites across the food chain can detect food-borne pathogens which would otherwise not be reported (e.g., before human exposure to the pathogen, or before a person becomes ill or seeks medical attention).[16] Therefore, sentinel site surveillance is not always generalizable, but provides useful information, as a complementary data source, about illness and its causes that is not available through other notifiable disease surveillance systems.[17]

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9 Alberta partially implemented Retail component in 2014.
10 Ontario sampling from January to March in the Ontario pilot site and from August to December in the second Ontario site.
11 Ontario sampling limited by outbreak of avian flu, began in August.
12 British Columbia sampling limited by outbreak of avian flu, began in September.
13 Water Sampling at Pilot Site in Ontario was initiated in 2005 and ended in 2013.
14 Water Sampling took place at five sites in Ontario during 2013 (continued from 2012), sampling at public swimming venues during summer (June-Aug).
15 British Columbia Pilot project for sampling from four British Columbia beaches took place in 2011-2012.
16 British Columbia collected surface water samples from January to December 2013.
17 British Columbia samples collected bi-weekly all year from five sites.
18 Ontario surveillance at the original pilot sentinel site ended, only partial human case surveillance data available (August to September, 2014) and are thus not included in the Short Report.

Although there are limitations to FoodNet Canada's sentinel site structure, this approach still produces useful data that can inform upstream prevention efforts, and simply require consideration of context and applicability when using the data. For example, risk factors for food-borne illness may vary significantly by province or region.[18] FoodNet Canada's 2013 comprehensive annual report indicates the "need to consider that the accuracy of generalizing these results beyond these communities decreases with increasing distance from the specific geographical area."[19]

Currently, FoodNet Canada's design is based on a five-sentinel site model, which would encompass approximately 10% of the population, qualifying as national coverage. [20] As additional sentinel sites are established, comprehensive information from laboratory and epidemiological analyses from all sites will provide more representative national trends in enteric disease incidence and exposure sources, in order to inform accurate source attribution estimates for all of Canada." [21]

Many key informants working internally and externally have indicated that FoodNet Canada provides valuable information related to three highly populated provinces in Canada where sentinel sites are operational. [22] The sentinel site methodology is an affordable alternative to census-style approaches to surveillance, but is unable to provide insight on incidence of food/water-borne enteric illness outside the catchment zones.[23] As such, geographic regions where a FoodNet Canada sentinel site does not exist may not benefit from the same advantages of risk identification and upstream prevention as participating regions.

Among the three active surveillance components of CIPARS (farm, slaughter, and retail meat), sampling design and regional/commodity coverage differ. Information collected through retail meat, farm, and abattoir sampling is integrated with passive surveillance components from a variety of sources to provide information about antimicrobial resistance at the national level (See Appendix 7). CIPARS is the only national surveillance program designed to monitor antimicrobial use and resistance in animals used for food in Canada.

CIPARS farm surveillance currently provides data on antimicrobial use and resistance originating in pigs and chickens.[24] Coverage for regional sampling within this category is aligned with the major provincial producers of these commodities, and encompasses FoodNet Canada's surveillance[19]: pork (Alberta, Manitoba, Saskatchewan, Ontario, Quebec), and broiler chickens (British Columbia, Alberta, Ontario, Quebec).[25] Differences in commodities sampled across the farm component are based on a targeted approach that takes into account the key farming industries of the region.[20] In light of those findings, it appears that the absence of farm-based CIPARS sampling of beef and turkey limits the program's ability to link findings to those observed through the abattoir and retail farm components of the surveillance program.

[19] CIPARS partners with FoodNet Canada in provinces operating a sentinel site.
[20] The most recent annual report describing CIPARS coverage was published in 2017 based on 2015 data.

The CIPARS slaughter component aims to provide nationally representative annual data on antimicrobial resistance for bacteria originating in healthy animals that are about to enter the food chain.[26] Abattoir surveillance is conducted for Salmonella and E. coli in animals that originated in Canada. Surveillance targets the three meat categories with the highest per-capita consumption rates in Canada: beef cattle, broiler chickens, and pigs.[21] Sampling occurs at 39 federally inspected slaughterhouses across Canada and the program describes the sampling as "a balance between acceptable statistical precision and affordability."[27] In 2015, the proportion of abattoirs selected for samples represented 70% of animals slaughtered at federally inspected abattoirs in Canada.[22] While this component is national in scope, it is important to note that there is no surveillance of antimicrobial resistance in animals originating outside of Canada. Some documents have noted that food safety surveillance currently faces broader gaps with respect to imported foods, as Canada currently has limited regulatory authority for these products. For the most part, imported food products are currently not captured in PHAC's surveillance systems. [28]

The retail component of CIPARS samples raw meat from the three commodities covered by the abattoir component: chicken, pork, and beef, as well as raw meat from turkey. Geographic locations for sampling were chosen based on Statistics Canada's population information,[23] and are selected to be representative of the entire region.[29] As of December 2017, CIPARS retail sampling of chicken, turkey, pork and beef are taking place in British Columbia, Saskatchewan, Ontario, and Quebec. Up until 2015, the Atlantic region also had a retail sampling program, but there were challenges in processing and analyzing the data in time for reporting, resulting in an absence of the region's data in the 2012[30] and 2013[31] annual CIPARS reports. By 2015, the Atlantic component of CIPARS retail surveillance was terminated due to funding constraints.[32] That same year, lower-than-expected sampling occurred in Ontario due to a lack of staff, and as a result, the program advised caution regarding the reliability of this data.[24]

In summary, during the period covered by this evaluation, collection of samples for CIPARS and FoodNet Canada were inconsistent for some commodities and regions. A few internal key informants stated that limitations in complete commodity coverage may reduce the comprehensiveness of the data being collected. An internal key informant

[21] Salmonella surveillance does not occur in beef cattle due to consistently low prevalence associated with this commodity.

[22] 90% of animals are slaughtered at federally inspected abattoirs. Thus, coverage is relatively complete.

[23] The sample locations are designed to capture 15-18 census divisions per region, and are chosen based on stratified random sampling methods, weighted by population.

[24] In the 2015 annual report for CIPARS, the program notes that "Unlike recent years (2013 and 2014), no data were presented in 2015 for the Atlantic region (a region that includes the provinces of New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland and Labrador) as retail sampling activities in this region were suspended due to budgetary constraints. Additionally, during the 2015 sampling year in Ontario, only a partial year's worth of retail sampling was conducted due to the availability of sampling technician staff. As a result, the sampling target and subsequent isolate yields in this province were not achieved and therefore, all retail data presented for Ontario in 2015 should be interpreted with caution." For more information, see: CIPARS. (2017). *CIPARS Annual Report 2015.* Retrieved from: http://publications.gc.ca/collections/collection_2017/aspc-phac/HP2-4-2015-eng.pdf

stated that CIPARS allows PHAC to gain an understanding of trends in antimicrobial resistance across the food chain, but that there are challenges in data coverage that cause limitations to making links to associated resistance rates in humans. Nonetheless, a few internal informants noted that, while information is not necessarily "complete" since PHAC collects and uses CIPARS' antimicrobial resistance samples and data when working with industry in a voluntary capacity, and due to sampling limitations for some components, it is often sufficient for its intended purpose.

Accessibility of Information

External key informants commonly noted that FoodNet Canada and CIPARS reports posted online are often out of date, despite the program's efforts to circulate the FoodNet Canada report to over 600 stakeholders via email as soon as it is available and prior to its public posting. However, a review of surveillance reports based on publishing dates (see Table 3) shows longer delays more recently, with no annual report or short report made available in 2016. The most recent FoodNet surveillance data available online, as of December 2017, was:

- the short report presenting 2015 surveillance data, posted in 2017; and
- the 2011-12 surveillance data, featured in the last annual report, posted in 2015.

The latest FoodNet Canada surveillance data available online seems to be restricted to condensed formats (e.g., short report and annual bulletin). The program has attributed some of the posting delays to preparations needed to make reports compliant with HTML requirements for posting public documents to the Canada.ca website.

As shown in Table 3 below, PHAC's reporting on antimicrobial resistance data also demonstrates significant posting delays, with the most recent publication posted in 2014, featuring surveillance data from 2012-13 (PHAC Human Antimicrobial Use) and 2000-2010 (CIPARS Human Antimicrobial Use Short Report). CIPARS Annual Reports are typically published following a two-year delay (e.g., the 2012 report was published in 2014). Consecutive reports followed the same delay.

PHAC staff have also indicated that improvements are needed to present CIPARS data in a way that resonates with stakeholders. Several internal key informants acknowledged that messaging from CIPARS and Canadian Antimicrobial Resistance Surveillance System (CARSS)[25] to date has not targeted the Canadian public, and furthermore, does not have an easy-to-find, dedicated posting area on the Canada.ca website. In addition, program staff noted that stakeholders have indicated that CARSS reports are not sufficient for their needs, citing a desire for a more fulsome presentation of the data.

[25] In spring, 2015, the Office of the Auditor General released an audit on antimicrobial resistance, which recommended that PHAC, in collaboration with provinces, territories, and other health stakeholders, should finalize its strategy to address weaknesses in surveillance, in order to ensure that adequate data on antimicrobial resistance is available. In response, PHAC noted that CARSS would provide more integrated reporting on antimicrobial resistance, including reporting on findings from CIPARS.

Table 3: Publishing Dates for Annual FoodNet Canada and Antimicrobial Resistance Surveillance Data

Surveillance Data included in Report	Report		Year Published [a] 2012	2013	2014	2015	2016	2017
	FoodNet Canada Reports	Short Report	2011	-	2013	2014	-	2015
		Biennial/ Annual Report	-	2009	2010	2011-2012	-	-
		Annual Bulletin	2012	2013 vol. 1	2013 vol. 2	2014	-	-
		Stakeholder Update	-	-	-	-	2015	-
	Anti-Microbial Resistance and Use Reports[33, 34, 35]	PHAC Human Antimicrobial Use	-	-	2012-2013	-	-	-
		CIPARS Human Antimicrobial Use Short Report	2011	-	2000 – 2010	-	-	-
		CIPARS Annual Report	-	-	2012	2013	2014	2015
		CARSS Report [26]	-	-	-	2013[b]	2014[c]	2015-2016[d]

[a] Publication dates for all reports (excluding the CARSS Reports) were provided with performance measurement data from the Centre for Foodborne, Environmental, and Zoonotic Infectious Diseases.

[b] Source: PHAC. (2015). *Canadian Antimicrobial Resistance Surveillance Systems (CARSS) Report 2015.*

[c] Source: PHAC. (2016). *Canadian Antimicrobial Resistance Surveillance Systems (CARSS) Report*, 2016. Retrieved from: https://www.canada.ca/en/public-health/services/publications/drugs-health-products/canadian-antimicrobial-resistance-surveillance-system-report-2016.html

[d] Source: PHAC. (2017) *Canadian Antimicrobial Resistance Surveillance Systems (CARSS) Report 2017.* Retrieved from: https://www.canada.ca/en/public-health/services/publications/drugs-health-products/canadian-antimicrobial-resistance-surveillance-system-2017-report-executive-summary.html

Furthermore, a few key informants identified difficulties in finding the programs' surveillance reports online. Anecdotally, several internal key informants indicated that information is generally easier to find and better tailored for the general population through the US Centers for Disease Control and Prevention (CDC) website, and tends to be the first online source for many Canadians to seek information about food-borne illness. As of December 2017, annual reports summarizing CIPARS and FoodNet Canada findings from 2012-2017 are available in summary only, with text directing readers to email PHAC for a full version of the report. Full versions of the reports, including the most recent CIPARS annual report published in September 2017, are listed as archived.

[26] CIPARS data up to 2014 were included in CARSS Report published in 2016. PHAC introduced the CARSS report in April 2015, and the first report included CIPARS data from 2013. For more information on the OAG report, refer to: *OAG (2015) 2015 Spring Reports of the Auditor General of Canada: Report 1 – Antimicrobial Resistance*. Retrieved from: http://www.oag-bvg.gc.ca/internet/English/parl_oag_201504_01_e_40347.html

In terms of report format, the program has indicated that it intentionally transitioned away from large annual reports. However, program documentation from knowledge translation discussions with stakeholders shows that there is a need for increased comprehensiveness in the short report. [36]

4.1.3 Detection

PHAC's food/water-borne detection activities include reference services, leading the methods transition to Whole Genome Sequencing, surveillance and research, as well as tool and methods development.

Reference Services

The National Microbiology Laboratory (NML) offers standardized information and testing for food/water-borne pathogens. The reference services offered include accredited and/or internationally standardized laboratory methods like serotyping, toxin typing, Pulsed-field Gel Electrophoresis (PFGE), and multiple locus variable number of tandem repeats analysis (MLVA).

The NML reference services are accessed by:

- PHAC food-borne enteric illness surveillance programs;
- provincial public health laboratories;
- the Canadian Public Health Laboratory Network;
- CFIA;
- hospitals and public health units;
- international public health partners;
- academic scientists; and
- applied research programs.[37]

A few external stakeholders specifically mentioned having access to the highest standard diagnostic testing available through the NML's reference services. These services include identification and serotyping for Listeria, Salmonella, and E. coli, and other pathogens, which can lead to the detection of an illness source linked to an outbreak. [38] Using reference services, stakeholder laboratories with lower capacity can access testing that provides more detailed identification of specific strains of food-borne pathogens causing enteric illness. Ultimately, reference services enable broader access to better evidence to inform outbreak investigations.

Client surveys administered by the program for activities that include and extend beyond food-borne enteric illness (2014) indicate a high level of satisfaction with expert opinions and consultations related to the reference services provided.[39] Furthermore, 95% of respondents agreed that the range of analytic laboratory procedures (assays) offered was appropriate, and all respondents agreed that those provided by the NML were of high quality.[40]

Whole Genome Sequencing

PHAC's NML began a transition to Whole Genome Sequencing for real-time surveillance in 2017, aligning itself with international pathogen testing standards. To date, PHAC has phased in the implementation of Whole Genome Sequencing by first pursuing centralized real-time surveillance of Listeria in January 2017, followed by Salmonella in April 2017.[27]

Whole Genome Sequencing provides greater potential for outbreak detection due to the method's enhanced level of detailed cluster detection, case categorization, and identification of pathogen characteristics (e.g., 'the complete genetic blueprint of an organism'[41]). In the context of food/water-borne enteric illness, Whole Genome Sequencing can provide a degree of precision that allows for the identification of the contaminated food source, as well as the region and factory site where it was produced.[42] Genomic technology can also help solve outbreaks in shorter timelines by genetically linking food sources to clusters of food-borne illness.[43] A retrospective study of PulseNet Canada priority pathogens (2017) found that, of the 3,139 isolates sequenced,[28] more than 50% of all "clusters/outbreaks analyzed in the study would have had different results" had Whole Genome Sequencing been used at the time of discovery.[44] Moreover, the study found the higher discriminatory capability of Whole Genome Sequencing also improves PHAC's capacity to identify connections in their antimicrobial resistance work.

The more detailed data produced by Whole Genome Sequencing also helps fill in certain gaps in public health intelligence. This is particularly evident in the case of Salmonella, where the standard PFGE testing, unlike Whole Genome Sequencing, is unable to distinguish between certain strains of Salmonella (such as Enteritidis), and whether cases are linked, random, or unrelated. The misclassification of isolates can also hinder the effectiveness of follow-up epidemiological investigations.[45] This presents public health risks, considering that 88,000 people in Canada contract Salmonella each year, contributing to one in four of all hospitalizations related to food-borne illness.[46]

Overall, as described by the US CDC, "when combined with enhanced laboratory computing (e.g., bioinformatics) capacities, these new technologies [Whole Genome Sequencing, Advanced Molecular Detection] are revolutionizing our ability to detect and respond to infectious disease threats."[47]

PHAC's food/water-borne illness laboratory-based detection work operates on a model of decentralized testing conducted by the provinces, with centralized intelligence coordinated by PHAC. In this model, provincial public health partner laboratories are responsible for conducting their own testing and analysis, and then providing the data to PHAC in order to enable the sharing of information nationally, and to support the

[27] Whole Genome Sequencing was initially used as early as 2015 to supplement outbreak response in Canada, with traditional methods first used to identify the clusters.

[28] Pathogens sequenced included: *Listeria monocytogenes*, *Salmonella Enterica* Serovars, Enteritidis, Heidelberg, and Typhimurium, as well as *Escherichia coli* O157:H7.

resolution of multijurisdictional outbreaks. During the current early stages of implementation, PHAC has been conducting Whole Genome Sequencing on behalf of provinces and territories due to capacity challenges at the local level.

Many portfolio and provincial laboratory stakeholders have commended PHAC's work in transitioning to Whole Genome Sequencing, highlighting the progress made, while supporting capacity building at the provincial level, all with limited resources. Many internal and external key informants also agreed that PHAC has provided Whole Genome Sequencing leadership throughout the implementation period, including:

- developing software and national bioinformatics platforms to enable the analysis and sharing of data;
- securing a grant through Public Safety Canada's Canadian Safety and Security Program (CSSP) to purchase eight MiSeq sequencers for provincial laboratory across the country;
- establishing a network connection;
- developing laboratory surveillance protocols and epidemiological interpretative criteria specific to the Whole Genome Sequencing method; and
- training and ongoing advice for provincial stakeholders. [48]

Key informants commonly mentioned PHAC's transition to Whole Genome Sequencing as one of the greatest successes of its food/ water-borne illness activity areas over the last five years. However, many internal and external key informants noted that Whole Genome Sequencing-specific resource challenges do exist at both PHAC and provincial levels, affecting the speed with which transition has occurred. The key capacity challenges raised and discussed below are linked to financial constraints, infrastructure, and expertise, which has resulted in significant workload increases for both laboratory and epidemiology staff.

A) Financial constraints

In response to the 2009 Weatherill Report, the NML received its initial funding[49] to support the introduction of faster laboratory testing method based on genomics, which was ultimately executed through a Listeria pilot project.[50] Since that time, PHAC has pursued the official implementation of Whole Genome Sequencing. As program key informants have indicated, this initiative has taken place without dedicated funding to support its broader implementation. The NML has continued to pursue genomics for food-borne illness despite budgetary constraints, as previous typing methodologies are insufficient to address gaps in available public health intelligence.

As mentioned earlier, the fully implemented Whole Genome Sequencing testing model for food/water-borne illnesses in Canada is based on provinces conducting their own testing and providing their results to PHAC for further analysis and centralized storage. However, for the early stages of implementation, PHAC was conducting all testing on behalf of provinces until they had built up their capacity to conduct their own genomics testing. The implementation plans projected provinces would be completing their own

Whole Genome Sequencing and analysis of results by the beginning of 2018.[51] The majority of key informants indicated that decentralization has been slower than anticipated, due to capacity challenges at the provincial level, which are often more pronounced than what is being experienced at the national level. The most common factor constraining provincial capacity mentioned by key informants was limited funding. At this point, only Ontario and Manitoba are equipped to complete their own Whole Genome Sequencing testing. This presents longer-term implications for PHAC's resources, as PHAC staff are completing Whole Genome Sequencing testing for provinces until provincial capacity has increased, in addition to their traditional workload.

The NML has developed supporting documents outlining the value of Whole Genome Sequencing and the need for additional resources, to assist provincial labs in their funding decisions. It remains to be seen if supporting documents have helped open funding conversations at the provincial level. A few key informants explained that, unlike Canada, the US CDC's successful implementation of Whole Genome Sequencing was based on a structure that allocated national funding to state-level public health laboratory sites. Funding was used to support training for staff in performing sequencing, acquiring sequencing supplies, and updating systems to support data analysis.[52,29] It is important to note that the US CDC is resourced at a different level than PHAC; as a result, a direct comparison is not possible. Nevertheless, the American example illustrates the potential positive impacts of wide-scale implementation of Whole Genome Sequencing. In their case, because of Whole Genome Sequencing, the US CDC has experienced a 350% increase in the number of outbreaks 'solved', and a 700% increase in the number of individual cases of illness linked to specific foods.[53] Of note, PHAC data from 2016 indicates that 60% (2.4 million) of food-borne illness cases in Canada come from unidentified sources of contamination.[54]

Several internal key informants have stated that they have been able to manage the transition to date. However, others have raised concerns about the sustainability of this work without additional resources.

B) Workload

Whole Genome Sequencing generates a greater amount of detailed data at a much faster rate. While more conventional methods typically require one to three weeks to generate data, Whole Genome Sequencing has expedited that timeframe to a few days.[55] This not only has workload impacts at the laboratory level, but also has implications for epidemiological work. That being said, the full extent of the impact of Whole Genome Sequencing on PHAC workload will not truly be known until at least one year's worth of data has been collected and analyzed. However, internal and external key informants have strongly agreed that the impact has been significant thus far.

[29] In 2013, the US CDC's Advanced Molecular Detection Initiative provided an investment of $30 million. (Newbern, E. (2016). *CDC Scales Up Use of NGS Technologies, Publishes First WGS Sequencing Data.* https://www.genomeweb.com/sequencing/cdc-scales-use-ngs-technologies-publishes-first-wgs-sequencing-data)

Since the implementation of real-time Whole Genome Sequencing surveillance of Salmonella, the NML has detected more than double the amount of Salmonella clusters compared to the average over the preceding years within the scope of this evaluation (2013 to 2016).[56] When compared to the average number of Salmonella clusters detected between 2012 and 2016, the number of clusters detected in 2017 increased by 182%. This has resulted in seven nationally coordinated outbreak investigations in six months, compared to one in the previous four years.

Beyond the actual sequencing of isolates, this change in technology has also required essential background work to establish surveillance protocols and epidemiological interpretive criteria. As is standard during a method transition period, food-borne pathogen samples undergoing Whole Genome Sequencing must also be typed in parallel with using the conventional laboratory techniques (PFGE and/or MLVA) to ensure sufficient validation data, and interpretation criteria are in place before the new method is accepted as the replacement.[57] PHAC has been using both methods on food-borne enteric illness pathogens on behalf of provinces, due to capacity deficits at the local level. Some internal key informants mentioned that PHAC's parallel testing period for provinces was not defined and is dependent on the speed with which they are able to transition.

C) Expertise

Following funding, the most commonly cited provincial capacity issue was the lack of expertise to assess Whole Genome Sequencing produced data. Many internal and external stakeholders noted that provinces often lack the epidemiological capacity to effectively deal with the exponentially higher levels of rapidly produced, detailed data. This is an important factor to acknowledge since, "improved technology and methods cannot eliminate the need for effective epidemiological data collection and collaboration with national and regional partners in other sectors, as well as relevant stakeholders".[58]

Some program staff indicated that provinces are overwhelmed by the amount of Whole Genome Sequencing data received from PHAC. Many PHAC staff indicated that provincial epidemiologists are unsure how to interpret the data. A few provincial stakeholders confirmed that there has been a steep learning curve for provincial epidemiologists and, at times, a continued lack of confidence in using the data.

Provincial key informants indicated a lack of capacity building opportunities specific to Whole Genome Sequencing for epidemiologists but noted that PHAC has provided support upon request. Internal staff indicated that the increasing workload demands, the time intensive nature of the requests, as well as with multiple extended epidemiologist staff vacancies, has often limited their ability to offer Whole Genome Sequencing interpretation advice and feedback to provinces. However, PHAC is represented on committees like the Federal-Provincial-Territorial Epidemiologists Whole Genome Sequencing Working Group and the Joint Laboratory-Epidemiology PulseNet Canada Steering Committee. There are in-depth laboratory-focused training opportunities offered by PHAC, including intensive week-long training sessions and weekly stakeholder meetings to discuss Whole Genome Sequencing laboratory protocols. NML has also been supplying materials to support funding requests at the provincial level. All stakeholders interviewed affirmed they are grateful for PHAC's overall expertise (not limited to Whole Genome Sequencing) and find that PHAC personnel are always available to provide advice and answers in a timely manner. In fact, key informants most frequently referenced PHAC's expertise and advice as the primary capacity building support provided by PHAC.

D) Infrastructure

Initially, provinces did not have the appropriate equipment for conducting Whole Genome Sequencing. The NML, with the help of a $1 million grant from the Canadian Safety and Security Program, has since purchased eight MiSeq sequencers for provincial public health labs across Canada, and provided the associated training to provincial public health labs on-site. NML personnel have also made themselves available for troubleshooting advice that falls within their expertise. In spite of securing sequencers for provincial counterparts, some internal key informants noted that many provinces still require financial resources to run the machines (e.g., cost of reagents).

The most commonly cited infrastructure challenge listed by internal key informants involves IT capabilities, including the need for fast connectivity. Current internet speeds prevent the efficient transfer of data among public health laboratory partners, a challenge identified department wide.[59] A few internal key informants mentioned that the use of a cable internet connection (e.g., CANARIE), which is significantly faster than corporate network infrastructure, would reduce genome sequence upload times. These internal key informants explained that it currently takes a province at least a full workday (8-10 hours) to upload one Salmonella sequence, and that this could be reduced to 15 minutes with the installation of a CANARIE connection. Currently, there are other federal departments with this high-speed connection, and the Government of Canada has begun a consolidation project targeted at the creation of a base infrastructure to enable direct science access to this faster connection.

Due to the large amount of data produced through Whole Genome Sequencing, there are also challenges in accommodating the storage of raw data. Storing a single bacterial isolate requires up to 2GB of hard drive space. Consequently, the NML's storage (which includes activities beyond food/water-borne illness) grows at an average of 30 TB per month.[60,30] Commercial cloud storage services are not a viable solution due to security requirements prohibiting the use of foreign servers to store Canadian data. The current IT challenges faced by PHAC are reflective of a laboratory system that was built over 50 years ago, established during an era of wet labs, and not designed to account for bioinformatics.[61] According to internal documentation, inadequate computing capacity in terms of network connectivity and data storage is

[30] Currently, the National Microbiology Laboratory at-large has access to 800 TB of storage, and anticipates having 2000 TB (2 PB) by the end of 2017-18 fiscal year, which it hopes will be sufficient capacity for the following five years.

inhibiting PHAC's ability to meet growing analytical needs. Furthermore, working with outdated scientific equipment may also pose a risk to the security of some data.[62]

Although the Whole Genome Sequencing transition period is a resource intensive phase, some internal key informants stressed that the long-term gains will create greater efficiency. Once fully implemented, Whole Genome Sequencing will replace five other laboratory tests including phage typing, serotyping, PFGE, and others used for identifying food/water-borne illness pathogens, which will result in the discontinuation of parallel testing. Currently, the cost of Whole Genome Sequencing is similar to conventional methods and is expected to decrease substantially in the next five years.[63, 64, 65] Furthermore, Whole Genome Sequencing data allows for a greater degree of adaptability, since the short-read sequences it produces can be manipulated in many different ways, consequently expanding its ability to inform other areas of research and surveillance.[66] The realization of these long-term reductions in cost is dependent on a fully implemented approach to Whole Genome Sequencing.

Surveillance and Research

PHAC's food/water-borne surveillance activities provide valuable data for PHAC and its partners to use in analysis that informs source attribution in outbreaks, risk information, and tracking changes in prevalence rates over time. [67] The surveillance systems managed by PHAC are populated based on food/water-borne pathogens and antimicrobial use information provided by provincial, territorial, and local public health authorities and laboratories, as well as Health Portfolio partners. PHAC's real-time food/water-borne enteric illness surveillance systems include:

- National Enteric Surveillance System (NESP); and,
- PulseNet Canada. [31]

NESP and PulseNet data are assessed together on a weekly basis to identify clusters of food/water-borne enteric disease, leading to the detection of, and response to, multi-jurisdictional outbreaks. The NML manages these findings, which stakeholders in the provinces and across PHAC use to inform their food/water-borne detection and response activities. Generally, key informants noted the strength of these real-time surveillance systems is their ability to provide timely and reliable pathogen information. This data serves to establish baselines that assist in the detection of food-borne illness outbreaks, as well as allowing users to improve their detection capacity, strengthening the surveillance system as whole. This positive impact to the system is also highlighted by the international reach of PulseNet's network, which includes a Memorandum of Understanding between the US and Canada, allowing the two countries to have read-only access to each other's data. The US CDC described this arrangement as the first of its kind in the world.[68] Domestically, PulseNet Canada's data has been used in the coordination of laboratory findings and epidemiological assessments for outbreak detection, including:

[31] For more information on the surveillance networks listed, refer to Appendix 3.

- E. coli in beef (2012);
- Salmonella in sprouted chia (2014);
- Listeriosis in bagged lettuce (16); and
- E. coli in flour (2017).

PHAC has also contributed to the food/water-borne illness knowledge base through the publication of peer-reviewed articles in scientific journals. During the calendar years of 2012-17, PHAC published 345 scholarly articles and academic papers related to food/water-borne illness. Articles published by PHAC during the evaluation period under review were referenced approximately 570 times to date. [32] In fact, of all articles in the *Food-borne Pathogens & Disease* scientific journal's 15 years of publication, a 2013 PHAC-produced article titled *Estimates of the Burden of Food-borne Illness in Canada for 30 Specified Pathogens and Unspecified Agents* has been the second-most cited to date, with 63 citations.[69] Management did indicate that the team produces a lot of valuable data and findings, but conceded that there is important material that has yet to be published because workload demands have prevented staff from drafting the articles.

Overall, stakeholders felt Canada has a strong food safety system. The collaborative nature of PHAC's surveillance systems, engaging stakeholders and PHAC as both contributors and users of the data, has added to the confidence in the systems and most likely its use.

Tool and Methods Development

PHAC's bioinformatics team has developed tools that program and external stakeholders use to leverage existing data in support of in-laboratory or in-field analysis. PHAC has been internationally recognized and is a national leader in the development of bioinformatics platforms. These tools produce microbiological analyses that can determine characteristics specific to pathogens causing enteric illness, and have also contributed to the development of methods for subtyping food-borne pathogens.

The NML has developed and collaborated in the development of bioinformatics tools like Salmonella In Silico Typing Resource (SISTR), E. coli In Silico Typing Resource (ECSTR) and Neptune (described in Appendix 4). These platforms facilitate the exchange of genomic information among public health partners, perform typing, and help to identify and disqualify food-borne illness cases, based on their genetic relatedness to particular clusters of interest. The NML's Super-Phy platform adds further value by predicting characteristics of a particular pathogen, including likeliness of antimicrobial resistance and virulence factors.[70]

As an example of the use of PHAC's bioinformatics tools, the CFIA and provincial public health laboratory partners described the positive impacts of the SISTR tool in particular. According to these stakeholders, the SISTR tool allows scientists to conduct analysis of

[32] Due to differences in performance data tracking, information about the number of references was missing for approximately 72 articles published during the evaluation period.

genomes at the laboratory level. This includes efficiently typing and predicting the physical characteristics of Salmonella samples based on their DNA sequence. SISTR further supports epidemiological analysis by allowing overlay with geographic and time-based features, as well as source attribution information.[71] Prior to SISTR, uncovering detailed typing information would require time-consuming tests (e.g., serotyping), but with this bioinformatics tool scientists are able to quickly predict important characteristics of pathogens causing enteric illness. There is even some evidence of provincial health authorities seeking to integrate their own research tools into the platform. SISTR has an average of 200 monthly users, including Health Portfolio members, provincial partners, and more than 70 international public health laboratory partners, who have submitted more than 14,000 genomes.[72] Users access genomic information on SISTR through a web-based platform - Integrated Rapid Infectious Diseases Analysis (IRIDA). Many external informants working across the Health Portfolio confirmed that SISTR has simplified information exchange between food safety partners, and has also simplified Salmonella serotyping for external stakeholders.

The bioinformatics team at the NML has adjusted tools to meet the needs of stakeholders based on user feedback, which may also account for the strong satisfaction stakeholders have expressed in regards to their bioinformatics tools.

4.1.4 Outbreak Response

PHAC is responsible for leading a coordinated response to multiple jurisdictional food-borne outbreaks in Canada. From the beginning of December 2012 to the end of January 2017, PHAC received 1,450 food-borne event notifications, of which 1,035 required further assessment by PHAC's epidemiologists to determine their relevance for future follow-up (see Table 4).

Table 4: Summary of Notifications Received and Actioned by PHAC[a]

Year	Number of notifications of enteric issues received	Number of issues with follow-up action	Number of Outbreak Investigation Coordinating Committees activated
2012	295	273	9
2013	251	208	7
2014	226	162	5
2015	205	134	11
2016	183	122	8
2017	290	138	12
TOTAL	**1,450**	**1,035**	**52**

[a] Internal Administrative Data provided by the Centre for Foodborne, Environmental and Zoonotic Infectious Disease.

Over the last three years, PHAC responded to the vast majority of notifications assessed (92-93%) within 24 hours. For the most part, this response rate has remained consistent in the last three years, despite fluctuations in the total number of notifications received (see Table 5).

Table 5: Percentage of Food-borne Illness Outbreak Responded to within 24 Hours of Notification [a]

Fiscal Year	Percentage of Responses within 24 Hours of Notifications[33]	Count of Notifications Received
2012/13	75%	18
2013/14	81%	20
2014/15	93%	28
2015/16	93%	50
2016/17	92%	31

[a] Internal administrative data provided by the Centre for Foodborne, Environment and Zoonotic Infectious Disease.

As discussed earlier, the implementation of Whole Genome Sequencing has had an impact on PHAC's detection and response work. Several key informants working across the Health Portfolio and in the provinces reported that their organizations were facing challenges in keeping up with the increased number of investigations because of Whole Genome Sequencing's improved detection capabilities. In 2016, prior to implementation, PHAC assessed 15 Salmonella clusters. In the first 10 months of 2017 following the NML's implementation of Whole Genome Sequencing for Salmonella pathogens, 82 clusters were assessed by PHAC. A few internal and external key informants indicated that epidemiologists were approaching the limit of what they can investigate, given the current level of human resources.

There is a lack of epidemiology capacity at the provincial level, which has been further exacerbated by the implementation of Whole Genome Sequencing, affecting the strength of networks in place to support PHAC's outbreak work.[34] Several internal key informants noted that PHAC uses provincial epidemiological data to detect and investigate multi-jurisdictional clusters of human illness but that provincial capacity to collect and analyze this data varies.

PHAC offers investigation-related training sessions, workshops and presentations to federal, provincial and territorial partners on such topics as: weight of evidence in epidemiological investigations, epidemiological questionnaire design and interview training, and tools related to food-borne illness outbreak investigations. Between 2012-17, approximately two-thirds (30) of the 47 training sessions offered by the Centre for Food-borne, Environmental and Zoonotic Infectious Diseases were targeted to local, provincial, and territorial partners, and were well-received by participants.

[33] The percentages do not account for notifications that are not significant or multi-jurisdictional. This includes cases acquired from travel, European cases, cases from the United States, outbreaks with single jurisdiction (including suspected botulism), non-food/zoonotic, and events with no human cases (recalls).

[34] For further information, refer to section 4.1.3. "Detection".

Ultimately, PHAC activated and led 52 Outbreak Investigation Coordinating Committees (OICCs) under the Food-borne Illness Outbreak Response Protocol (FIORP) during 2012-17.[73] An OICC is activated when similar food-borne infections are present in multiple jurisdictions, based on the severity and potential scope of the outbreak. Each committee regroups partners involved in a specific outbreak and aims to coordinate a multi-agency response to the outbreak. [74]

The FIORP was established in 2010 and is updated on an ongoing basis to reflect lessons learned. It has commonly been described as a best practice among internal and external stakeholders, having had a positive impact on PHAC's approach to resolving multi-jurisdictional outbreaks of food-borne enteric illness in humans. A few external stakeholders noted that participation in the OICC supports their awareness of important information in ongoing outbreak investigations, and that collaboration in resolving outbreaks has since become routine for all partners.

Food-borne outbreak response can be complex and requires a collaborative approach to ensure its resolution. This is evident when considering the 2016-17 E. coli O121 outbreak associated with flour. In late December 2016, PHAC PulseNet Partners detected an outbreak of E. coli O121 in several provinces across Canada. PHAC worked to conduct an epidemiological investigation to identify the source of the outbreak. They also assumed the responsibility for coordinating the investigation and response among multiple partners. During this outbreak, PHAC collaborated with external partners across the provinces and territories, within the Health Portfolio, and in affected industries to detect and respond to the outbreak, and implement activities to prevent future illnesses. Figure 1 below illustrates PHAC's responsibilities to lead the OICC ensuring collaboration among food safety, provincial, and territorial partners during the outbreak, while simultaneously participating actively in the outbreak investigation until its close.

Figure 1: Outbreak Detection and Response in Action: E. coli O121 Outbreak (Flour)

Context: The strain of E. coli (O121) linked to the 2016 outbreak found in flour is more difficult to detect compared to common strains of E. coli (such as O157). Challenges linked to its detection include: lack of fulsome surveillance coverage, including: inconsistent collection of data at the local level, subtyping requires additional screening processes, and, in the case of this particular outbreak, its presence in dry foods had been rare despite a similar outbreak in the US the year prior.

DETECTION

- Newfoundland and BC provincial public health laboratories independently posted similar food-borne human illness cases to PulseNet Canada on December 29, 2016.
- PHAC's NML immediately identified the two cases, on opposite coasts, as potentially being linked.
- PHAC's laboratory staff used conventional methods (e.g., serotyping) to explore any further connection, but the results were ambiguous.
- PHAC staff noticed irregularities and felt further investigation was warranted. Laboratory staff applied Whole Genome Sequencing, reducing the testing time from 24 hours (serotyping) to 3 hours, also allowing for the identification of family groupings. Results were provided to provincial lab partners within 1-2 days of receipt.
- During the outbreak, PulseNet Canada continued to be used as a source to share real-time public health information.

Throughout the outbreak, the Canadian Millers Association actively communicated food safety information to consumers that was consistent with PHAC key messaging. They also produced flour food safety infographics and videos, and have since advocated for food safety labelling on flour packages.

RESPONSE

- The Outbreak Investigation Coordinating Committee (OICC) was convened by PHAC on January 4, 2017 and held weekly meetings until April when the last case of E. coli O121 was detected.
- The first Public Health Notice was released on January 13, 2017.*
- Initial epidemiology investigations did not uncover a food source signal, since the base of infected individuals varied significantly.
- PHAC gathered information from the US CDC on how they had determined flour as the source of their E. coli outbreak the year prior.
- PHAC epidemiologists transitioned from administering a standardized questionnaire to having one epidemiologist conduct open-ended interviews about food exposure, and incorporating the US CDC questions which had helped determine the signal (e.g., "do you lick the spoon after baking?").
- Once the signal (flour) was determined, CFIA eventually identified a patient that still had contaminated flour in its original packaging at home. The sample was then sent to PHAC's laboratory for Whole Genome Sequencing analysis.
- CFIA then approached the retailer to obtain two bags of Robin Hood brand flour, which after being tested, were confirmed as a source of the E. coli outbreak. This resulted in the issuing of a product recall by CFIA.
- While there were calls by certain OICC partners to consider the outbreak closed, PHAC provided epidemiological curve data indicating reporting delays, and were able to determine that individuals exposed to contaminated flour would not yet have presented as ill.
- The Agency's 13th public health notice on the outbreak was released on June 2, 2017, which indicated the outbreak was over (see Appendix 5).

*There were significant inconsistencies between PHAC and CFIA's public case count reporting. (See section 4.2.1 *Public Communication*)

In addition to their role in response coordination, PHAC also periodically consults with industry partners to develop interventions during food-borne outbreaks. Examples of this collaboration include:

- In 2016, certain frozen berries sold at Costco were found to be infected with Hepatitis A, and a product recall was issued. [75] Under PHAC and CFIA guidance, Costco responded by offering free Hepatitis A vaccinations for customers who had purchased the affected berries during the period of February to May 2016.
- As indicated in Figure 1, during the 2017 E. coli O121 outbreak, the Canadian National Millers Association (CNMA) was in regular communication with PHAC to understand the breadth of the outbreak's impact. As a result, they used PHAC expertise in the development of their videos and website messaging on safe handling of raw flour. The Canadian National Millers Association also advocated for food safety labelling on flour packing, which has since been implemented for certain brands (e.g., Robin Hood). [76]

Public Health Capacity

Following the 2008 Listeriosis outbreak in Canada, which resulted in the death of 23 Canadians, the 2009 Weatherill Report found weaknesses in Canada's preparedness and response to the food-borne illness outbreaks. In particular, the report identified issues linked to surge capacity and a lack of clarity around the roles and skills required by staff who are called upon to help with outbreak response.[77]

Following the release of the Weatherill Report, a $112.9 million[35] horizontal initiative led by CFIA was launched in 2012, with the intention of enhancing food-borne illness prevention, detection, and response in Canada. This included such initiatives as the expansion of FoodNet Canada and the hiring of additional PHAC full-time equivalents (FTE). In addition, PHAC and Health Canada received a total of $10.5 million of ongoing funding ($6.6 million and $3.9 respectively). PHAC had determined that their internal mobilizations were not well-defined, and that a mix of technical skills was required, as well as improving surge capacity that could accommodate relief for mobilized staff.[78] As a result, a portion of the ongoing capacity funding PHAC received to enhance public health capacity was allocated to the Health Security Infrastructure Branch for the development of core competencies for epidemiologists and the All Events Response Operations platform (AERO).

The Development of Core Competencies for Epidemiologists

With the additional funding, PHAC hired two additional staff members to support the development of workforce competency tools, with a focus on food-borne outbreaks. Internal staff indicated that these tools are currently used to guide training and staffing decisions, with the goal of ensuring that the proper breadth of epidemiological capacity

[35] Of the total $112.9 million spending authority, Health Portfolio partners received the following amounts: CFIA ($60.4 million over four years); PHAC ($33 million over five years); and Health Canada ($19.5 million over five years).

support is in place to respond to food-borne illness outbreaks. This was confirmed in a few internal interviews, which noted that the competency profiles were useful in streamlining training objectives and ensuring that the proper epidemiology-specific learning requirements are satisfied.

The Development of the All Events Response Operations (AERO) Platform

AERO was developed with the intention of establishing and maintaining a national epidemiological surge capacity to support public health outbreaks, but has since been expanded to include resources to support the Health Portfolio Operations Centre. Staff resources are recruited from PHAC, with plans to open registration to Health Canada and CFIA staff in the future. The platform:

- hosts a roster of staff from across PHAC that can be drawn upon to help support a coordinated response to public health events;
- tracks and processes surge capacity requests coming from partner organizations (e.g., the World Health Organization, provinces and territories);
- manages temporary related staff assignments (i.e., mobilizations);
- collects data that will inform surge capacity planning by identifying outstanding needs and gaps; and
- shares preparedness and response capacity building information (e.g., resources, announcing training sessions).[79]

As of December 2017, AERO was not fully operational, but staff recruitment began in June 2017 and epidemiologist deployment has been tracked through the platform since September 2015. According to PHAC's *Health Portfolio Mobilization Strategy for Event Response*, "once AERO is launched, it is expected to serve as the main roster tool for all Health Portfolio mobilizations."[80] As of December 2017, no performance data was available to demonstrate whether AERO had led to improvements in mobilization or changes in emergency response.

The few key informants aware of AERO's link to food-borne illness capacity building funding expressed that it is likely that AERO will not be a resource that PHAC's food-borne illness teams will need to rely on. The reason is that Budget 2012 has provided resources to allow PHAC's food-borne illness outbreak response team to address outbreaks within their current resource level.

4.2 Information to Canadians

4.2.1 Public Communication during Outbreaks

According to some internal key informants, the coordination of external communication by Health Portfolio partners, in response to multi-jurisdictional outbreaks, has been improving over time. The key areas of improvement identified include: a more consistent and harmonized approach to communication among the Outbreak Investigation

Coordinating Committee (OICC) members, as well as greater alignment in public communications by Health Portfolio partners.

Over the past five years, PHAC has adopted a proactive approach to communicating public health risks, occasionally communicating on emerging issues before consulting the OICC. According to some internal key informants, this has caused confusion for, and negatively affected relationships with, provincial and territorial public health partners. In 2016, PHAC developed a communications triggers guidance tool to provide a more standardized approach and greater clarity on how and when PHAC makes decisions about public communications during outbreak investigations. These triggers account for the severity, scope, cause of the food-borne illness event, as well as risk perception, which, when assessed together, can determine whether PHAC pursues a high, medium, or low communication strategy.[81,82] Anecdotally, a few internal key informants acknowledged that the introduction of these procedures have helped ensure transparency in communication exchanges between the partners.

Communicating to Canadians about food safety is a shared mandate between PHAC, Health Canada, and CFIA. During a multi-jurisdictional outbreak, PHAC is responsible for publishing Public Health Notices online, and CFIA issues Food Recall Warning Notices.[83] While recall warnings and public health notices for the same event contain information specific to the outbreak, CFIA and PHAC have historically faced challenges with consistent messaging due to different case threshold criteria. While PHAC accounts for all human illness cases linked to a pathogen with matching genetic fingerprints, CFIA only considers cases that have a confirmed link to a specific product. Some internal key informants noted that communicating different rates of infection has led to confusion among industry and the public as to the severity of the risks associated with outbreaks in progress. These differences can be quite significant, as evidenced by outbreak communication surrounding the E. coli O121 (flour) outbreak in 2017. CFIA's Food Recall Warning Notice for that particular outbreak listed only one case of E. coli associated with the recall, while PHAC's public health notice during the same period identified a total of 30 cases linked to the outbreak.[84] [36]

The majority of CFIA and PHAC key informants agreed that communication products could be better aligned when a national outbreak is active and a food recall warning is issued.[85] The two agencies have since agreed to a new communication template and process, whereby CFIA no longer lists human illness case counts in their Food Recall Warning Notices, and instead links Canadians to PHAC's Public Health Notices for metrics and further illness-related information. This new template was first implemented during the October 17, 2017 recall of frozen uncooked breaded chicken products contaminated with Salmonella.[86] Due to the recent implementation of the communications process, this evaluation is unable to assess the impact or effectiveness of the new template.

[36] See Appendix 5 for a recap of the discrepancies between reported CFIA and PHAC case counts during the 2017 E. coli O121 (flour) outbreak.

4.2.2 Prevention Messaging

Federal Approach to Food-borne Illness Prevention

Canada is ranked as one of the strongest food safety systems in the world,[87] however approximately four million Canadians still contract a food-borne illness each year.[88] In the last few years (2012-15), infection rates for common food-borne illnesses like Salmonella have increased. [89] Although PHAC's food/water-borne activities includes the goal of preventing related health risks during outbreaks, a few Health Portfolio key informants did allude to a lack of clarity surrounding each agency's role in contributing to overall prevention efforts. As it stands, according to the previous 2012 program evaluation, PHAC provides expertise, if needed, to Health Canada and CFIA for regular communication activities on risk prevention. PHAC's *2013-2018 Food Safety Strategic Plan* further identifies that, although PHAC's publicly focused food safety mandate has typically been more centered on prevention messaging during multi-jurisdictional outbreaks, there have been more recent commitments between CFIA and Health Canada to proactively engage the Canadian public and stakeholders in a more coordinated approach, for the purpose of food-borne illness prevention.[90]

The majority of key informants also identified a need to better inform Canadians on preventing food-borne illness infections. FoodBook data indicates that 1 in 10 Canadians may use practices that put them at risk of contracting a food-borne illness[91].[37] Overall, evaluation evidence has pointed to the need for targeted approaches to address specific gaps in relation to the safe handling of certain products, outreach to populations adversely affected by certain food-borne illness (e.g., Canadians traveling abroad), and the accessibility of messaging targeted at Canadians.

Knowledge Gaps

PHAC research illustrates there are strengths and weaknesses in the knowledge surrounding safe food handling of particular food products. Overall, Canadians were well informed about washing their hands (93%) and preparation surfaces (93%) after coming into contact with raw meat or poultry. In general, FoodBook respondents were most aware of risks associated with chicken (86%) and hamburger (80%), and awareness levels declined significantly (less than 40%) related to products such as soft unpasteurized cheese, alfalfa sprouts, unpasteurized juice. It is also important to note that while 86% of Canadians surveyed through FoodBook were aware of general risks associated with chicken, only 23% of respondents were aware of risks associated with raw chicken nuggets. [92] In keeping with this finding, a few internal key informants also indicated that Salmonella in chicken continues to be one of the most significant food-borne illness issues in Canada.

[37] Although public awareness was often cited as affecting the effectiveness of food-borne illness prevention, it is also important that it is one of many factors (e.g., industry practices).

Information and Distribution Tailored to the Public

Many internal key informants acknowledge that current PHAC products are not written or presented in a format that is easily digestible for Canadians, since the materials are targeted to an informed audience. Specifically, key Informants raised concerns related to the length of reports, the technical nature of some of PHAC's products, and the language used. These challenges are not unique to PHAC. Health Canada's March 2014 evaluation of their food safety activities also flagged information gaps in related consumer education, and noted there was limited information available with language targeted at different audiences (e.g., health professionals, Canadians), and that this could affect levels of public awareness.[93] In the case of PHAC's antimicrobial resistance evidence, many internal key informants often noted that it has not been presented in a way that resonates with the public, and, as a result, is not used as effectively as possible to inform Canadians of antimicrobial resistance risks.

In comparison, many external and internal key informants indicated that the United States Centres for Disease Control and Prevention (US CDC) produces and disseminates information in comprehensive, yet easy to understand formats, and tailors its products to different audiences. They also noted that US CDC information is easy to access, whereas PHAC's food/water-borne enteric illness information is often difficult to find on PHAC's website. As a result, many internal and external key informants explained that US CDC resources often serve as the primary source that Canadians consult for information on food/water-borne illness prevention and protection.

Also of note, some internal and external stakeholders indicated challenges in finding the appropriate information online, as well as with the medium used to make the information available. In addition, some key informants also indicated the need to stay relevant by reaching the public through social media. PHAC's food-borne illness messaging through social media is concentrated on outbreak response communication. However, some key informants argued that there is a barrier to food-borne illness prevention because the public is inclined to look for information during outbreaks, rather than looking for everyday risk reduction information outside of an outbreak. PHAC has partially accounted for this by including safe food handling tips in public health notices that are relevant to the food-borne outbreak at hand.

4.3 Program Spending

PHAC receives ongoing funding for its food/water-borne enteric illness activities as delivered through the National Microbiology Laboratory (NML), and the Centre for Food-borne, Environmental and Zoonotic Infectious Diseases (CFEZID). Also, as discussed in section 4.1.4, the Health Security Infrastructure Branch (HSIB) received funding to improve core competencies for epidemiologists, and improve surge capacity through the development of the AERO platform. Over the 2012-13 to 2016-17 period covered by this evaluation, expenditures from each of the three areas totaled the following: $50M for NML; $34.3M for CFEZID; and $2.3M for HSIB.

On average, as shown in Table 6, all three areas of PHAC delivered their activities within budget during this period. There were, however, some fluctuations across areas and years in terms of proportion of budget spent.

National Microbiology Laboratory (NML)

NML underspent its budget in every year covered by the evaluation, with the exception of one. It overspent its budget by six percent in 2016-17, which was the year that Whole Genome Sequencing implementation was launched. It is too early for the financial data to identify the effects related to this implementation. Moreover, the allocations for both Operations and Management (O&M) and salary were also lower for 2016-17 when compared to previous years.

Overall, when averaged out over the five years covered by the evaluation, NML's expenditures accounted for approximately 90% of their planned budget.

Centre for Food-borne, Environmental and Zoonotic Infectious Diseases (CFEZID)

CFEZID also underspent its budget in all years except 2013-14, where expenditures were slightly above budget. There are notable cases of lapsed CFEZID funding, including approximately $2.4 million in fiscal years 2012-13 and 2015-16, mainly due to unspent funds allocated to staff salaries. For example, funds were lapsed in 2012-13, since the additional funding granted under the CFIA-led horizontal initiative addressing the Weatherill report recommendations was allocated late in 2012. Consequently, the implementation of the additional capacity-building activities related to this funding could not be fully performed by the end of the fiscal year. This funding aimed to support the hiring of additional PHAC full-time equivalents (FTE) for outbreak response.

Overall, when averaged out over the evaluation period, CFEZID's expenditures accounted for approximately 85% of their planned budget.

Public Health Capacity Funding Allocated to the Health Security Infrastructure Branch

The proportion of planned budget spent shows significant fluctuation across the years, with approximately half of budgeted funds spent in 2012-13 and 2016-17, countered by overspending in 2013-14 (167%) and 2015-16 (112%).

When averaged out over the five years under the scope of this evaluation, HSIB spent 94% of their total planned budget.

Table 6: Variance Between Planned Spending vs Expenditures[a] 2012-2013 to 2016-2017 ($000)

Year	Planned Spending ($)			Expenditures ($)			Variance ($)	% planned budget spent
	O&M	Salary	TOTAL	O&M	Salary	TOTAL		
NML Food/Water-borne Enteric Illness Activities								
2012-13	2,772	2,198	4,970	3,070	1,320	4,391	579	88%
2013-14	5,612	9,208	15,320	4,760	7,408	12,679	2,641	83%
2014-15	4,371	8,057	12,666	3,543	7,365	11,053	1,614	87%
2015-16	3,226	8,389	13,189	2,838	7,686	11,971	1,217	91%
2016-17	2,519	6,707	9,376	2,748	7,004	9,902	-526	106%
TOTAL[b]	**18,500**	**34,559**	**55,521**	**16,958**	**30,783**	**49,995**	**5,526**	**90%**
CFEZID Food/Water-borne Enteric Illness and Antimicrobial Resistance Activities								
2012-13	3,191	5,230	8,421	2,875	3,142	6,016	2,405	71%
2013-14	2,147	4,337	6,484	2,324	4,344	6,668	-184	103%
2014-15	2,346	5,464	7,810	2,491	4,839	7,330	480	94%
2015-16	2,453	6,075	8,528	1,670	4,428	6,098	2,430	72%
2016-17	2,600	6,590	9,190	2,184	6,042	8,225	965	89%
TOTAL[b]	**12,737**	**27,697**	**40,434**	**11,544**	**22,794**	**34,337**	**6,097**	**85%**
Public Health Capacity Funding Allocated to the Health Security Infrastructure Branch								
2012-13	190	296	486	82	182	264	222	54%
2013-14	190	296	486	182	628	810	-324	167%
2014-15	190	296	486	148	265	413	73	85%
2015-16	190	296	486	125	419	544	-58	112%
2016-17	190	296	486	44	209	253	233	52%
TOTAL[b]	**950**	**1,479**	**2,429**	**581**	**1,703**	**2,284**	**145**	**94%**

[a] Data Source: Financial data provided by Office of Chief Financial Officer.
[b] The sum of O&Ms and salary may not correspond exactly to the total column due to rounding of numbers.

5.0 Conclusions and Recommendations

The findings from the review of the Public Health Agency of Canada's (PHAC) food/water-borne illness activities during the period of January 2012 to October 2017 have led to the following conclusions and recommendations.

5.1 Conclusions

PHAC contributes to Canada's strong food safety system by providing surveillance capabilities, bioinformatics technology, and the ability to manage outbreak responses. Evaluation findings provide evidence of PHAC's contributions to informing food safety interventions, as well as detecting and responding to food/water-borne enteric illness outbreaks.

The strength of PHAC's prevention, detection, and response activities for food/water-borne enteric illness lies within its staff expertise and the resources they provide to both stakeholders and Canadians, aimed at informing and motivating each group to take informed action to protect themselves against potential risks.

Overall, stakeholders found the program areas' expertise to be beneficial in helping build their own capacity through skills development, resource support, increased access to surveillance information, and assistance with source attribution during outbreaks. There were some challenges identified on how the information is presented and shared with stakeholders.

PHAC has also led and supported provinces in the methods transition to Whole Genome Sequencing, allowing for more detailed pathogen analysis. However, the transition is facing capacity challenges as Whole Genome Sequencing generates an exponentially higher amount of data to assess. To date, this has resulted in the identification of more food-borne enteric illness outbreaks, while no additional laboratory and epidemiological resources have been provided at both PHAC and provincial levels.

Despite the current resource constraints resulting from the impact of Whole Genome Sequencing implementation, PHAC consistently responds to the majority of outbreak notifications within 24 hours. Furthermore, all internal and external key informants perceived the Food-borne Illness Outbreak Response Protocol (FIORP) as a best practice for federal, provincial, and territorial response guidelines and frameworks.

There are opportunities to improve consistency in public communications from Health Portfolio partners during a food-borne illness outbreak. A new communications process has been implemented to help address inconsistent messaging that, in the past, led to confusion among affected industries and the public as to the severity of the risks associated with outbreaks in progress.

5.2 Recommendations

1. **PHAC should update its plan for the Whole Genome Sequencing implementation, taking into consideration the capacity constraints experienced in the initial phase of the transition within both PHAC and the provinces.**

In light of provincial capacity constraints and the additional demand that the transition to Whole Genome Sequencing has put on PHAC's resources (e.g., human, financial, and technological), PHAC should revisit its implementation planning to reflect realistic timelines and the resources needed to support a continued roll-out of this new technology. A full implementation of Whole Genome Sequencing will allow PHAC to align itself with international pathogen testing standards. As well, compared to other conventional methods, Whole Genome Sequencing provides a greater degree of precision on pathogen characteristics, which can improve the identification of contaminated food sources and potentially lead to faster resolution of outbreaks.

2. **Improve access to upstream surveillance information and ensure the content of upstream information products is adapted to the needs of stakeholders.**

PHAC should improve how upstream surveillance information is shared with stakeholders and tailor the content of such information products to better address their needs. Overall, improvements made should aim to ensure that stakeholders have timely access to the upstream surveillance information they need to carry out their work. As part of this effort, PHAC should also examine options to better document how its upstream prevention data is used to support policy change.

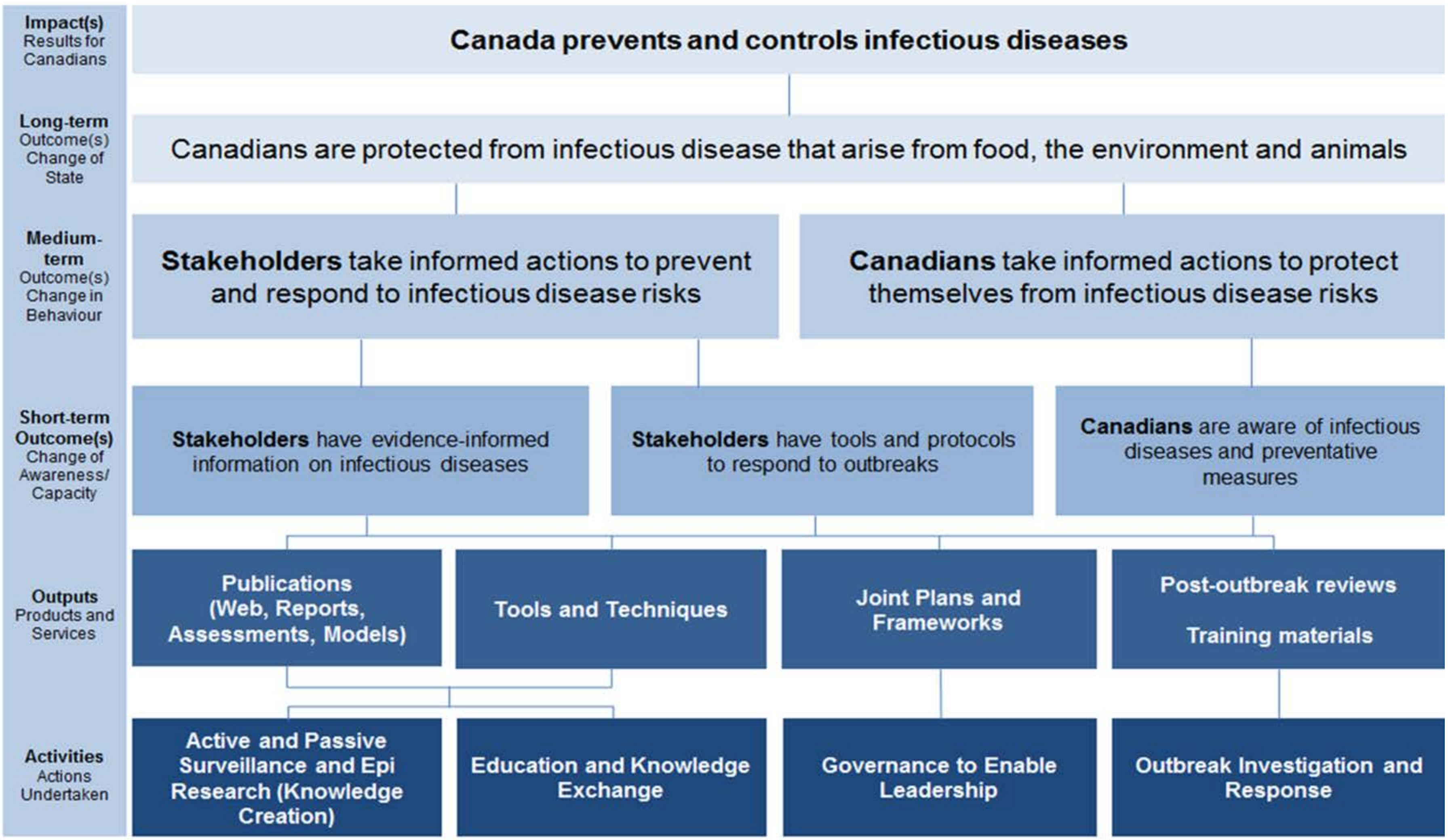
3. **Monitor the effectiveness of the Canadian Food Inspection Agency (CFIA) and PHAC's new coordinated communications process for outbreak investigations.**

CFIA and PHAC have made efforts to remedy inconsistent public communication during food-borne outbreaks by embarking on a new coordinated communications process. In light of its recent implementation, the evaluation was unable to assess the extent of its impact, although anecdotally key informants were complimentary of the new approach. Nevertheless, PHAC should continue to monitor the effectiveness of the newly implemented coordinated communications approach for outbreaks in order to ensure public messaging is consistent, clear, and accessible, as well as easily linked and navigable between PHAC and CFIA's websites.

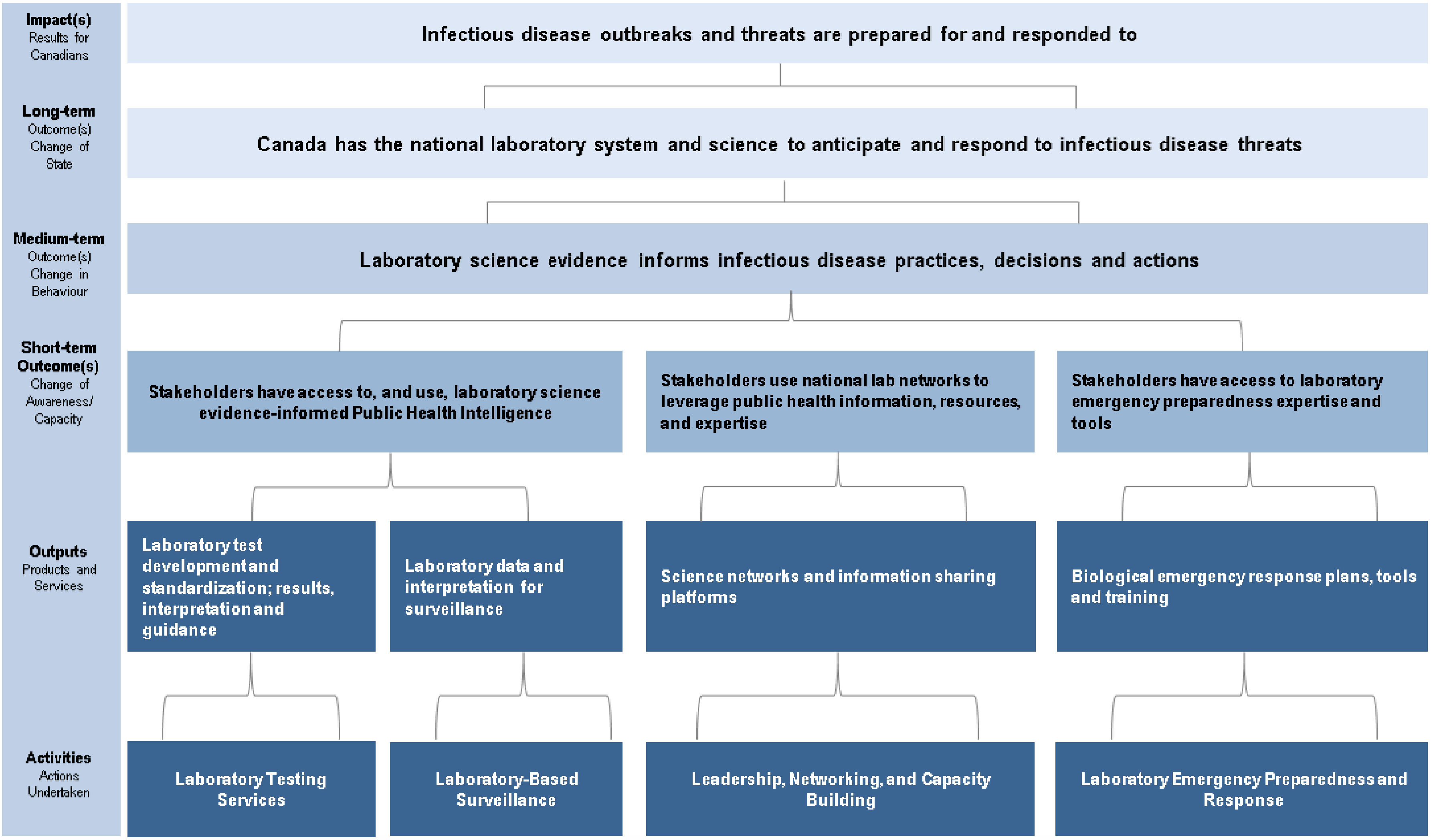
4. **Explore how PHAC could support messaging to Canadians on food/water-borne illness prevention.**

There is a need for improved communication to Canadians regarding the prevention of food-borne illness, as 1 in 10 Canadians continue to use practices that put them at risk of contracting food-borne illness. Although PHAC's role related to food/water-borne illness prevention is specific to messaging during an outbreak, and Health Canada is the primary Health Portfolio partner that communicates to Canadians outside of an outbreak, PHAC should still examine how it can support other Health Portfolio partners in improving messaging to Canadians on food/water-borne enteric illness prevention. With that in mind, it is recommended that PHAC build off their commitment, as outlined in the *2013-2018 Food Safety Strategic Plan*, to more proactively engage the Canadian public and stakeholders in a more coordinated Health Portfolio approach to food-borne illness prevention.

Appendix 1 – Centre for Food-borne, Environmental and Zoonotic Infectious Diseases Logic Model



Appendix 2 – Laboratory Science Leadership Logic Model



Appendix 3 – PHAC Food/Water-borne Surveillance Systems

System	Description	PHAC's Role
National Enteric Surveillance Program (NESP)	NESP provides centralized analysis and reporting on enteric illness across Canada, as confirmed in provincial public health laboratories. The program monitors enteric disease trends to identify potential clusters and outbreaks of enteric disease.[94]	PHAC is the administrator for the NESP. PHAC receives weekly aggregate totals of enteric illness from public health laboratories and conducts centralized analysis of information to detect emerging and priority enteric diseases at the national level. PHAC then returns weekly reports to the submitting laboratories and other stakeholders. PHAC also integrates NESP data with PulseNet Canada surveillance and international surveillance efforts. [95]
Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS)	CIPARS collects, integrates, and analyses data on antimicrobial use and resistance for select enteric bacteria from animals, humans, and retail meat across Canada. CIPARS uses this data to communicate trends in antimicrobial resistance in meat food sources and in humans across Canada.[96]	PHAC conducts active surveillance for three components of CIPARS: this includes retail meat, farms, and abattoirs. For these three components, the program actively collects samples of enteric bacteria in select geographic regions to determine the prevalence of antimicrobial resistance across Canada. PHAC also receives isolates and data from various stakeholders through passive data collection for the remaining surveillance components of CIPARS: human, animal clinical isolates, feed and feed ingredients, and reported domestic sales of antimicrobials for use in animals. The program integrates data from these sources to provide an analysis of antimicrobial use and resistance.[97]
PulseNet Canada	PulseNet Canada is an online network of federal, provincial, and territorial public health and food regulatory agencies. Using a secure web-based discussion forum and database, PulseNet allows provincial and federal public health laboratories to rapidly share DNA fingerprints for food/water-borne	PulseNet Canada is coordinated by PHAC. Participating provincial public health laboratories, called PulseNet members, submit DNA fingerprints for all cases of E. coli and most cases of Salmonella detected within their regions. Using this data, the National Microbiology Laboratory conducts centralized analysis to identify genetically related clusters.[99] When a province identifies a cluster of enteric illness, the respective public health laboratory will post the information to

System	Description	PHAC's Role
	pathogens. The purpose of PulseNet Canada is to detect multijurisdictional clusters of food-borne illness using DNA.[98]	PulseNet Canada databases to inform other provinces of an emerging issue. Based on this information, database managers at PHAC look to identify any genetically related clusters, and when one is identified they will lead the posting of a multi-provincial cluster. [100] It is also possible for PulseNet members to submit pathogens to PulseNet Canada for whole genome sequencing. In this case, the data are returned to the member and resulting analysis is posted on the database. [101] PulseNet Canada holds a Memorandum of Understanding (MOU) with their American counterpart, run by the US CDC. The MOU grants each country read-only access to the others' PulseNet database.
FoodNet Canada	FoodNet Canada conducts surveillance of food-borne pathogens in humans, retail food samples, on farms, and in local water. It is the only surveillance source capturing the full farm-to-fork continuum in Canada. FoodNet Surveillance is based on a sentinel site approach. Data are collected in partnership with provincial public health authorities in three sites located in British Columbia, Alberta and Ontario. [102]	PHAC facilitates FoodNet Canada, a multi-partner initiative implemented through local public health units and provincial public health laboratories. [103] Through sentinel sites, PHAC and provincial partners conduct active surveillance by collecting samples from retail food, farms, and local water sources to detect the prevalence of particular food/water-borne pathogens causing enteric illness. In each sentinel site, enhanced human surveillance takes place alongside active surveillance in each site. Sampling is integrated with CIPARS, where appropriate, for retail food and farm surveillance. [104] PHAC performs centralized analysis of trends emerging from data collected at each site to assist in determining what food and other sources are making Canadians ill, and to track diseases over time.[105]

Appendix 4 – PHAC Bioinformatics Systems

Below is a list of Bioinformatics Systems developed by PHAC for analysis of pathogens causing food/water-borne illness.

Bioinformatics System	Description[106]
E. coli *In Silico* Typing Resource (ECSTR)	• A web-accessible tool that enables users to upload E. coli genome sequence data and perform several *In silico* typing analysis simultaneously. • The *Food Safety Strategic Plan Program Report 2015 – 2016*[107] outlines plans to validate and implement Whole Genome Sequencing for serotyping human cases of E. coli using ECSTR for routine use at the NML and the decentralization of provincial labs.
EpiQuant	• Analytical tool developed between PHAC and academia for analyzing and quantifying the level of similarity between bacterial isolates based on their epidemiological metadata[108]. • Aimed at public health professionals using molecular data in the context of epidemiological analysis, including Whole Genome Sequence data. • Will be used for the Genomics Research and Development Initiative – Antimicrobial Resistance (GRDI-AMR) project to identify likely transmission pathways for antimicrobial resistant Salmonella in the poultry production system. [109]
Galaxy	• An open source, web-based platform for data-intensive biomedical research[110]. • Since January 2017, 131 researchers have used Galaxy. The majority of the Galaxy users are PHAC employees (119 users). External users are also beginning to use this tool: other federal and provincial departments and universities make up 19 Galaxy users, and there are 12 international users.[111]
Integrated Rapid Infectious Diseases Analysis (IRIDA)	• The IRIDA platform is a secure, web-based system to automatically integrate epidemiological, genomic, and other laboratory data. Integrated data are used to perform epidemiological analyses during outbreaks of infectious disease, including food/water-borne illness. • The IRIDA platform hosts open-source tools to manage and analyze next-generation sequencing data. [112] • The IRIDA platform is accessible to public health professionals and academics outside of PHAC.
Neptune	• The National Microbiology Laboratory developed Neptune to enable the rapid discovery of genomic content that will differentiate between groups of bacteria.

	• The software identifies patterns that are shared by one group, but absent from other groups. These sequence patterns often correspond to genes that are responsible for the observed differences between the two groups. • These genes can then inform new research or form the basis for food-borne pathogens. • Neptune is commonly used by biologists at the National Microbiology Lab. The program was used during the 2008 Listeriosis outbreak.[113]
Salmonella *In Silico* Typing Resource (SISTR)	• A web-accessible tool that enable users to upload draft *Salmonella* genome sequence data and perform several *In-silico* (by means of computer modeling) typing analysis simultaneously. • The *Food Safety Strategic Plan 2015 – 2016* outlines plans to validate and implement whole genome sequencing for serotyping human cases of Salmonella using SISTR for routine use at the National Microbiology Laboratory and the decentralization of provincial labs.[114] • Has an average of 200 users each month, and more than 14 000 users have submitted genomes.[115]
SuperPhy	• Provides pre-computed analyses of publicly available E. coli genomes. • Allows real-time analysis of virulence and antimicrobial resistance determinants. • Allows identification of biomarkers for groups of genomes. • Designed for users in the fields of medicine, epidemiology, ecology, and evolution. • Analysis created for SuperPhy will be integrated into the IRIDA platform.

Appendix 5 – Summary of Public Communications during the Outbreak of E. coli O121 Associated with Flour in Canada

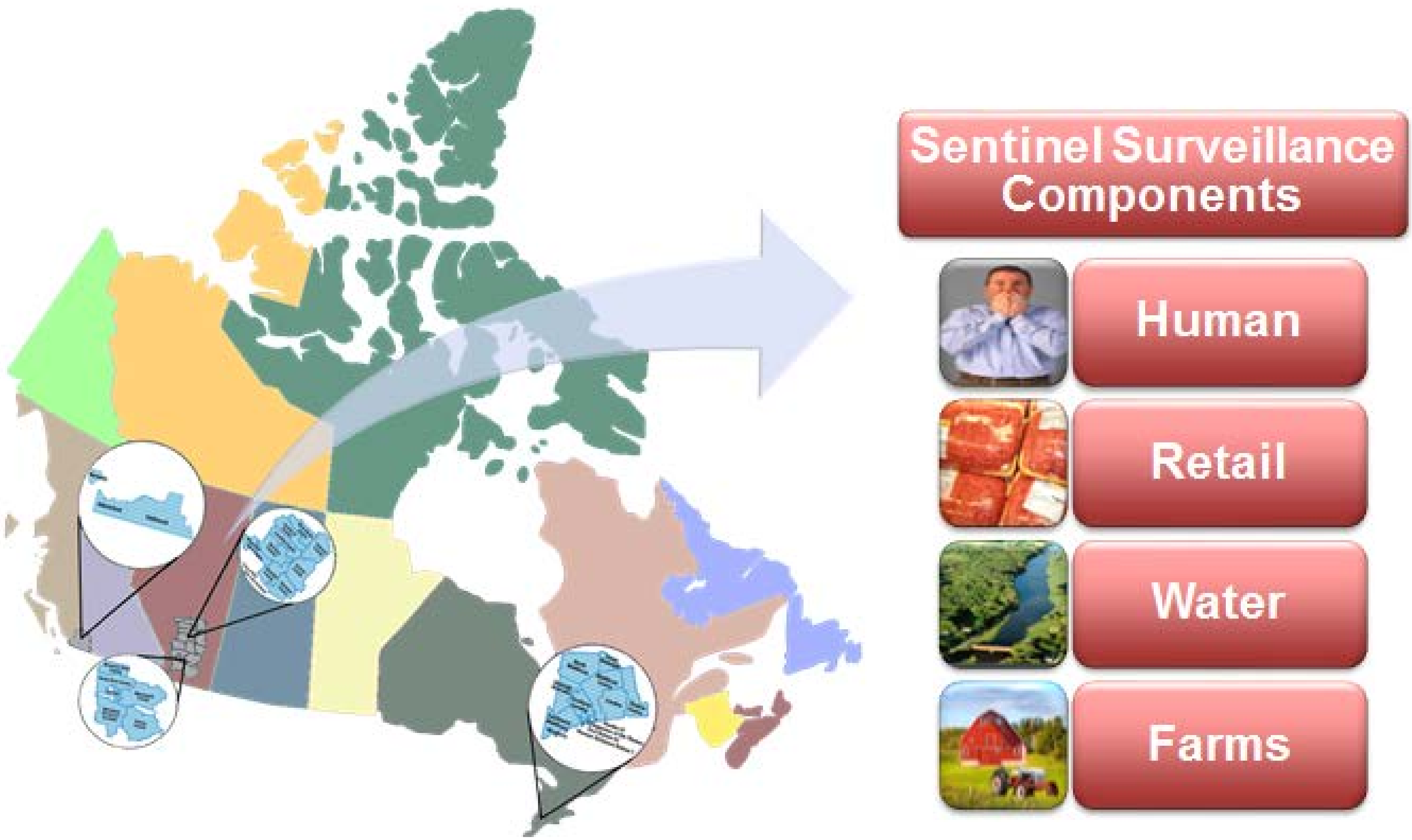
Context: CFIA and PHAC share responsibilities for communicating to Canadians during an outbreak investigation. Information provided by PHAC in public health notices, and by CFIA in food recall warnings, help Canadians to make informed decisions about the risks associated with particular food products during an active outbreak of food-borne illness. While PHAC reports on the total number of genetically related illnesses associated with an outbreak, CFIA's reporting threshold for the number of illnesses linked to the same outbreak is associated with confirmed relatedness to an identified product. CFIA could potentially issue a product recall with no confirmed illnesses. At times, the information on illnesses reported by PHAC and CFIA has varied significantly due to the difference in reporting thresholds, as evidenced during the outbreak of E. coli O121 in flour summarized below.

	Public Health Agency of Canada		**Canadian Food Inspection Agency**	
Communications Product	Public Health Notices		Food Recall Warnings	
What is it?	PHAC releases Public Health Notices to advise Canadians of a known public health risk associated with a food product. Information in the notice typically includes the source of illness, number of people who have become ill or hospitalized, and steps consumers can take to reduce risk.		CFIA releases Food Recall Warnings identify food products that have been recalled due to health risks, including contamination with enteric pathogens. Information in the notice typically includes the names and lot codes of the recalled products, the number of illnesses associated with consumption of the product, and actions consumers should take if they consumed the recalled product.	
When did it get updated?	When additional food sources associated with the outbreak were recalled, or when additional illnesses or hospitalizations associated with the outbreak were reported.		When additional products were recalled due to contamination with the same pathogen.	
	Summary of information in Public Health Notices for the Outbreak of E. coli O121 in Flour		**Summary of information in Recall Notices for the Flour and Flour Products due to E. coli O121.**	
Date	Illnesses Reported		Illnesses Reported	Recalled Products
January 13, 2017	12 Illnesses, 4 Hospitalizations	-	-	-
January 26, 2017	14 Illnesses, 5 Hospitalizations	-	-	-
February 2, 2017	16 Illnesses, 5 Hospitalizations	-	-	-

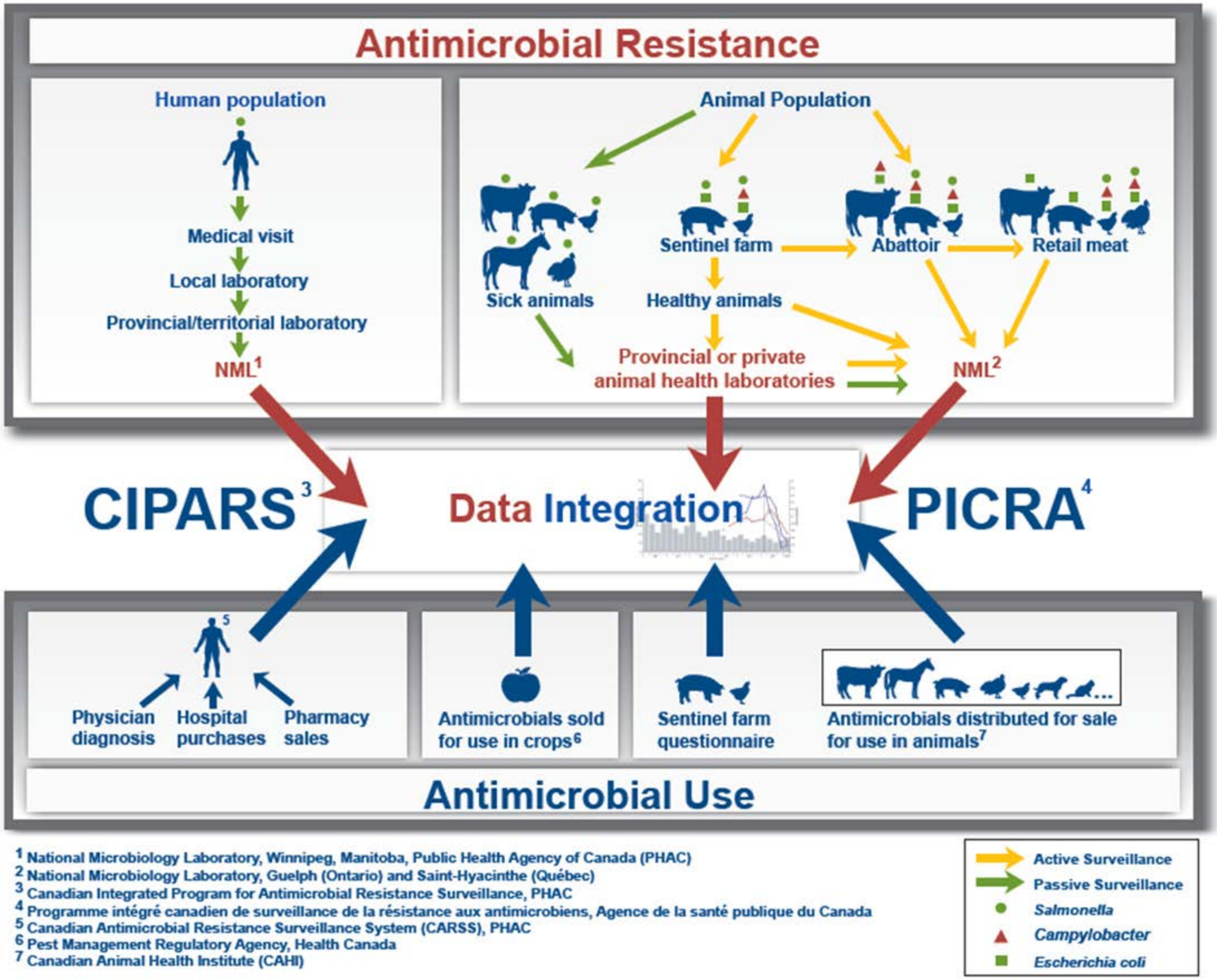
February 27, 2017	20 Illnesses, 5 Hospitalizations	-	-	-
March 13, 2017	24 Illnesses, 5 Hospitalizations	-	-	-
March 28, 2017	25 Illnesses, 6 Hospitalizations	**Source Identified:** Robin Hood All Purpose Flour	1 Illness	**Recalled:** Robin Hood All-Purpose Flour
April 4-5, 2017	26 Illnesses, 6 Hospitalizations			**Updated:** Additional lot codes for recalled Robin Hood All-Purpose Flour
April 12-13, 2017	26 Illnesses, 7 Hospitalizations	**Sources Updated:** Flour products from Ardent Mills	0 Illnesses	**Updated:** Various brands of flour and flour products from Ardent Mills
April 16-20, 2017	28 Illnesses, 7 hospitalizations			**Updated:** Various additional brands of flour and flour products from Ardent Mills
April 25, 2017	-	-		**Updated:** Additional flour and flour products from Ardent Mills
April 28, 2017	28 Illnesses, 7 hospitalizations	**Sources Updated:** Additional flour products from Ardent Mills		**Updated:** Unsweetened tart shells and pie lids from Mom's Pantry
May 10, 2017	-	-		**Updated:** Tart shells sold by The New Food Box
May 11th, 2017	29 Illnesses, 8 hospitalizations	**Sources Updated:** Additional flour products from Ardent Mills		**Updated:** Various pie and tart shells recalled.
May 18, 2017	30 Illnesses, 8 hospitalizations		-	-
May 26, 2017	-	-	0 Illnesses	**Updated:** Various additional brands of flour and flour products.
June 2, 2017	**Final Update:** "This notice has been updated to reflect that the outbreak appears to be over and the outbreak investigation has been closed."		-	-

June 15-29, 2017	-	-	0 Illnesses	**Seven Additional Updates:** Products included various flour and flour products from Robin Hood and Lost Acre Variety, as well as some pie and tart shells, and cookie dough.
Notes	• All PHAC Public Health Notice updates after the source of the E. coli was identified refer to the CFIA recall notice for additional information on recalled food products.		• All CFIA Recall Notices updates refer to the PHAC Public Health Notice for further information. • On the occasions where CFIA reported zero illnesses during this recall, they also included a caution that "there have been reported illnesses associated with flour; however, at this time, there have been no confirmed illnesses associated with the products identified in this Food Recall Warning."	

Appendix 6 – FoodNet Canada Components [116]



Appendix 7 – CIPARS Components[117]



Appendix 8 – Evaluation Description

Evaluation Scope

The scope of the evaluation of PHAC's food/water-borne enteric illness activities covered the period of January 2012 to October 2017. The previous evaluation of PHAC's activities in this area determined an ongoing need and role for the Government of Canada to contribute to Canada's food safety system in its current capacity. As a result, the evaluation is based on a review of the program areas' performance, with a particular focus on three key areas:

- Whole Genome Sequencing;
- Public communications related to food/water-borne outbreaks; and
- Public health capacity built through food-borne response funding provided after the 2008 Listeriosis outbreak for activities outside of CFEZID and NML within PHAC.

The evaluation also explores PHAC's work in the area of antimicrobial resistance and its link to the food supply, through its management of the Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS).

The evaluation is designed to address the intended outcomes of PHAC's food-borne and water-borne enteric illness activities, and provides insight on the evaluation issues and questions presented in the following table.

Evaluation Issues and Questions

Evaluation Core Issues	Proposed Lines of Questioning
Performance	
1. Achievement of Expected Outcomes	1. To what extent have the expected outcomes of PHAC's Food/Water-borne Enteric Illness Activities been achieved? **Immediate:** 1.1 To what extent do stakeholders have evidence-based information on infectious diseases of food/water-borne illness diagnosis, prevention, and response? 1.2 To what extent do stakeholders have access to PHAC-produced scientific evidence and expertise? 1.3 Has PHAC had the necessary capacity to detect new emerging disease outbreaks and trends? 1.4 To what extent are Canadians aware of infectious diseases and preventative measures? 1.5 Are Canadians receiving timely and clear information on food/water-borne risks and preventative measures?

Evaluation Core Issues	Proposed Lines of Questioning
	Intermediate: 1.6 To what extent do stakeholders take informed actions to prevent and respond to food/water-borne infectious diseases? 1.7 To what extent do Canadians take informed actions to protect themselves from diseases? **Long Term:** 1.8 To what extent have Canadians, and others living in Canada, been protected from food/water-borne health risks as a result of PHAC's activities?
2. Demonstration of Efficiency and Economy	2. To what extent have program activities demonstrated efficient and economic distribution of resources? 2.1 Has funding dedicated to addressing food-borne and water-borne enteric illness been spent as intended? **2.2** To what extent has the program achieved an effective and sustainable distribution of resources?

Data Collection and Analysis Methods

Sources of information used in this evaluation included a document review, financial data review, and key informant interviews. Data were analyzed by triangulating information gathered from the different sources and methods described below.

- **Document, File and Data Review.** Over 100 documents and files were provided to evaluators from program representatives working within PHAC and supporting internal services. Evaluators also accessed documents that were publicly available on Canada.ca. Sources reviewed included annual reports, strategic and planning documents, performance measurement data, Memoranda of Understanding, minutes from committee meetings, and documents used for regular program administration.

- **Review of Financial Data:** An analysis of planned and actual spending was conducted based on information provided by PHAC's Chief Financial Officer Branch.

- **Interviews with 41 key informants**: Evaluators conducted 26 interviews with PHAC employees working within PHAC, including CFEZID, NML, and internal stakeholders supporting activities outside the program areas. Due to the shared responsibility for food/ water-borne enteric illness across the federal and provincial governments, evaluators interviewed 15 key informants external to PHAC. External key informants included respondents working with other federal departments and agencies (8), provincial and territorial organizations (5), international organizations (1), and academia (1). Evaluators used content analysis methods to identify key themes emerging across multiple interviews, aligned with questions identified in the evaluation matrix. In all cases, evaluators identified the frequency with which informants working internally and externally spoke to a particular theme.

Endnotes

[1] Public Health Agency of Canada. Public Health Agency of Canada Food Safety Strategic Plan 2013 – 2018. Internal Document.

[2] Public Health Agency of Canada [PHAC]. (2016). *Yearly food-borne illness estimates for Canada*. Retrieved from: https://www.canada.ca/en/public-health/services/food-borne-illness-canada/yearly-food-borne-illness-estimates-canada.html

[3] World Health Organization [WHO]. (2017). *Antimicrobial resistance in the food chain*. Retrieved from: http://www.who.int/foodsafety/areas_work/antimicrobial-resistance/amrfoodchain/en/

[4] Public Health Agency of Canada. (2010). Food-borne Illness Outbreak Response Protocol (FIORP) 2010: To guide a multi-jurisdictional response. Retrieved from https://www.canada.ca/en/public-health/services/infectious-diseases/foodborne-waterborne-zoonotic-infections/illness-outbreak-response-protocol-fiorp-2010-guide-multi-jurisdictional-response.html.

[5] Public Health Agency of Canada. (2010). Food-borne Illness Outbreak Response Protocol (FIORP) 2010: To guide a multi-jurisdictional response. Retrieved from https://www.canada.ca/en/public-health/services/infectious-diseases/foodborne-water-borne-zoonotic-infections/illness-outbreak-response-protocol-fiorp-2010-guide-multi-jurisdictional-response.html.

[6] Health Canada. (2012). *Food* Safety. Retrieved from: https://www.canada.ca/en/health-canada/services/food-nutrition/food-safety.html?_ga=2.260589453.

[7] Health Canada. (2012). *Food* Safety. Retrieved from: https://www.canada.ca/en/health-canada/services/food-nutrition/food-safety.html?_ga=2.260589453

[8] Health Canada. (2009). Codex Alimentarius. Retrieved from https://www.canada.ca/en/healthcanada/services/food-nutrition/international-activities-codex-alimentarius.html

[9] PHAC. (2017) *FoodNet Canada Short Report 2015*. Retrieved from: http://publications.gc.ca/collections/collection_2017/aspc-phac/HP37-17-1-2015-eng.pdf

[10] Ciampa, N. and Public Health Agency of Canada. (2016). FoodBook: An Update and Highlights from the Canadian Food, Water and Animal Exposure Study. Internal Document.

[11] Public Health Agency of Canada (2015). *Foodbook Report.* Retrieved from: https://www.canada.ca/en/public-health/services/publications/food-nutrition/foodbook-report.html

[12] Evaluation Services – Public Health Agency of Canada. (2012). Evaluation of Food-borne Enteric Illness Prevention, Detection and Response Activities at the Public Health Agency. Retrieved from https://www.canada.ca/en/public-health/corporate/mandate/about-agency/office-evaluation/evaluation-reports/evaluation-food-borne-enteric-illness-prevention-detection-response-activities.html

[13] Public Health Agency of Canada. (7 April 2017). *PHAC Data Quality Assessment Report for FoodNet Canada.* [Internal Document]. Pp. 4

[14] Public Health Agency of Canada. (2013). *FoodNet Canada (formerly known as C-EnterNet): Reducing the burden of gastrointestinal disease in Canada*. Retrieved

from: https://www.canada.ca/en/public-health/services/surveillance/foodnet-canada/overview.html

[15] Allos, B.,M., Moore, M.R., Griffin, P.M., Tauxe, R.V. (2004) "Surveillance for Sporadic Food-borne Disease in the 21st Century: The FoodNet Perspective." *CID 38 (3).*: pp. S115 – S120

[16] Allos, B.,M., Moore, M.R., Griffin, P.M., Tauxe, R.V. (2004) "Surveillance for Sporadic Food-borne Disease in the 21st Century: The FoodNet Perspective." *CID 38 (3).*: pp. S115 – S120

[17] Centres for Disease Control and Prevention (2012)., "Lesson 5: Public Health Surveillance, Section 4: Identifying or Colleting Data for Surveillance" *Principles of Epidemiology in Public Health Practice, Third Edition: An Introduction to Applied Epidemiology and Biostatistics*. Atlanta: U.S. Department of Health and Human Services. (Online: https://www.cdc.gov/ophss/csels/dsepd/ss1978/SS1978.pdf)

[18] Allos, B.,M., Moore, M.R., Griffin, P.M., Tauxe, R.V. (2004) "Surveillance for Sporadic Food-borne Disease in the 21st Century: The FoodNet Perspective." CID 38 (3).: pp. S115 – S120

[19] Public Health Agency of Canada (2017). FoodNet Canada Annual Report 2013. Retrieved from: http://publications.gc.ca/collections/collection_2017/aspc-phac/HP37-17-2013-eng.pdf

[20] PHAC (2017) FoodNet Canada Short Report 2015. Retrieved from: http://publications.gc.ca/collections/collection_2017/aspc-phac/HP37-17-1-2015-eng.pdf

[21] PHAC. (2015) *FoodNet Canada Annual Report 2013.* Retrieved from: http://publications.gc.ca/collections/collection_2017/aspc-phac/HP37-17-2013-eng.pdf

[22] PHAC (2017) *Sentinel Sites*. https://www.canada.ca/en/public-health/services/surveillance/foodnet-canada/sentinel-sites.html

[23] World Health Organization. (2017) *Sentinel Surveillance*. Retrieved from: http://www.who.int/immunization/monitoring_surveillance/burden/vpd/surveillance_type/sentinel/en/

[24] Ibid.

[25] PHAC. (2017). CIPARS Annual Report 2015. Retrieved from: http://publications.gc.ca/collections/collection_2017/aspc-phac/HP2-4-2015-eng.pdf

[26] PHAC. (2017). CIPARS Annual Report 2015. Retrieved from: http://publications.gc.ca/collections/collection_2017/aspc-phac/HP2-4-2015-eng.pdf

[27] PHAC. (2017). CIPARS Annual Report 2015. Retrieved from: http://publications.gc.ca/collections/collection_2017/aspc-phac/HP2-4-2015-eng.pdf

[28] Mussar, K. (2015). Canada's Safe Food for Canadians Act and Regulations.

[29] CIPARS. (2014). *CIPARS Annual Report 2012*. Retrieved from: http://publications.gc.ca/collections/collection_2014/aspc-phac/HP2-4-2012-1-eng.pdf

[30] CIPARS. (2014). *CIPARS Annual Report 2012*. Retrieved from: http://publications.gc.ca/collections/collection_2014/aspc-phac/HP2-4-2012-1-eng.pdf

[31] PHAC. (2015). *CIPARS Annual Report 2013*. Retrieved from: http://publications.gc.ca/collections/collection_2015/aspc-phac/HP2-4-2013-1-eng.pdf

[32] PHAC. (2017). *CIPARS Annual Report 2015*. Retrieved from: http://publications.gc.ca/collections/collection_2017/aspc-phac/HP2-4-2015-eng.pdf

33 Public Health Agency of Canada. (2015). Canadian Antimicrobial Resistance Surveillance Systems (CARSS) Report 2015.

34 Public Health Agency of Canada. (2016). Canadian Antimicrobial Resistance Surveillance Systems (CARSS) Report, 2016. Retrieved from: https://www.canada.ca/en/public-health/services/publications/drugs-health-products/canadian-antimicrobial-resistance-surveillance-system-report-2016.html

35 Public Health Agency of Canada. (2017) Canadian Antimicrobial Resistance Surveillance Systems (CARSS) Report 2017. Retrieved from: https://www.canada.ca/en/public-health/services/publications/drugs-health-products/canadian-antimicrobial-resistance-surveillance-system-2017-report-executive-summary.html

36 Public Health Agency of Canada. (2015). *Knowledge Translation (KT) Discussion*. Internal Document.

37 World Organisation for Animal Health. (Unknown). *OIE Reference Laboratory for Salmonellosis*. PowerPoint Presentation. Internal Document.

38 Public Health Agency of Canada. (2011). *Enteric Disease Program*. Retrieved from https://www.nml-lnm.gc.ca/eb-be/ED-ME-eng.htm.

39 Public Health Agency of Canada. (2014) *National Microbiology Laboratory – Results of the Client Satisfaction and Needs Assessment Survey, 2014*. Internal Document.

40 Public Health Agency of Canada. (2014). *National Microbiology Laboratory. Results of the Client Satisfaction and Needs Assessment Survey 2014*. Internal Document.

41 Rumore, J. (2017). PulseNet Canada Development Project: Retrospective Whole Genome Sequencing of PulseNet Canada Priority Pathogens: Retro 1000 Project.

42 United States Food and Drug Administration. [FDA]. (2016, June 30). *GenomeTrakr: Transforming Food Safety* [video file]. Retrieved from https://www.youtube.com/watch?v=oFv_82p94QU&feature=youtu.be

43 United States Centres for Disease Control and Prevention [CDC]. (No Date). AMD – Advanced Molecular Detection at a Glance. Retrieved from: https://www.cdc.gov/amd/pdf/amd-at-a-glance-final-508.pdf

44 Yachison, C., Yoshida, C., … Nadon, C. (2017). The Validation and Implications of Using Whole Genome Sequencing as a Replacement for Traditional Serotyping for a National Salmonella Reference Laboratory. *Frontiers in Microbiology, 8,* 1-9.

45 Yachison, C., Yoshida, C., … Nadon, C. (2017). The Validation and Implications of Using Whole Genome Sequencing as a Replacement for Traditional Serotyping for a National Salmonella Reference Laboratory. *Frontiers in Microbiology, 8,* 1-9.

46 PHAC. Food Safety Infographic

47 Centers for Disease Control. (2016). Advanced Molecular Detection (AMD) and Response to Infectious Disease Outbreaks. Retrieved from https://www.cdc.gov/amd/index.html

48 Reimer, A., Nadon, C., Graham, M., Van Domselaar, G., Tschetter, L., Christianson, S., PulseNet Canada Steering Committee. (2016). *PulseNet Canada Genomics Implementation roadmap.* [Internal Document].

49 Government of Canada (July 2009) Report of the Independent Investigator into the 2008 Listeriosis Outbreak. Retrieved from: https://www.cmc-cvc.com/sites/default/files/files/ListeriaIndependentInvestigatorReport_July212009.pdf

[50] Government of Canada. (December 2011) *Action on Weatherill Report Recommendations to Strengthen the Food Safety System: Final Report to Canadians.* Retrieved from: http://publications.gc.ca/collections/collection_2012/agr/A22-551-2011-eng.pdf.: Pp. 27-28.
[51] Reimer, A. et. al. (16 October 2013). PulseNet Canada Genomic Epidemiology Roadmap. [Internal Document]
[52] United States Centers for Disease Control. (2016). Whole Genome Sequencing. Retrieved from: https://www.cdc.gov/pulsenet/pathogens/wgs.html
[53] Public Health Agency of Canada. (2016). PHAC Laboratory Technology Modernisation. Internal Document.
[54] Public Health Agency of Canada. (2016). Yearly food-borne illness estimates for Canada. Retrieved from https://www.canada.ca/en/public-health/services/food-borne-illness-canada/yearly-food-borne-illness-estimates-canada.html#ov.
[55] Lindsey, R., Pouseele, H., Chen, J., Strockbine, N. & Carleton, H. (2016). Implementation of Whole Genome Sequencing (WGS) for Identification and Characterization of Shiga Toxin – Producing *Escherichia coli* (STEC) in the United States. *Frontiers in Microbiology*. 7:766. doi: 10.3389/fmicb2006.00766.
[56] Public Health Agency of Canada. (2018). [Number of Salmonella Clusters Detected, 2012-2017]. Internal Document.
[57] Riemer, A., Graham, M; Nadon, C., PulseNet Canada Steering Committee. (2013). PulseNet Canada Genomic Epidemiology Roadmap. [Internal Document].
[58] Food and Agriculture Organization of the United Nations. (2016). Applications of Whole Genome Sequencing in food safety management.
[59] Science & Technology Infrastructure Initiative. (2016). Concept Document, Version V.1.5C. Internal document.
[60] Science & Technology Infrastructure Initiative. (2016). Concept Document, Version V.1.5C. Internal document.
[61] Science & Technology Infrastructure Initiative. (2016). Concept Document, Version V.1.5C. Internal document.
[62] Science & Technology Infrastructure Initiative. (2016). *Concept Document, Version V.1.5C*. [Internal document.]
[63] Reimer, A.; Nadon, C., Graham, M., Van Domselaar, G., Tschetter, L., Christianson, S., PulseNet Canada Steering Committee. (2016). *Genomics Implementation Roadmap: July 2016*. [Internal Document].
[64] Nadon, C., Van Wall, I., Gener-Smidt, P., Campos, J., Chinen, I., Concepcion-Acevedo, J., Gilpin, B., Smith, A.M., Kam, K.M., Perez, E., Kubota, K., Takkinen, J., Nielsen, E.M., Carleton, H., FWD-NEXT Expert Panel. (28 June 2017). "PulseNet International: Vision for the Implementation of Whole Genome Sequencing (WGS) For Global Food-Borne Disease Surveillance." *Eurosurveillance 22* (23).
[65] Riemer, A., Graham, M; Nadon, C., PulseNet Canada Steering Committee. (2013). PulseNet Canada Genomic Epidemiology Roadmap. [Internal Document].
[66] Yachison, C., Yoshida, C., … Nadon, C. (2017). The Validation and Implications of Using Whole Genome Sequencing as a Replacement for Traditional Serotyping for a National Salmonella Reference Laboratory. *Frontiers in Microbiology, 8,* 1-9.
[67] Public Health Agency of Canada. (2017). Key Informant Discussion – PHAC's FoodNet Canada: Understanding Stakeholders' information needs. Internal Document.

[68] United States Centers for Disease Control and Public Health Agency of Canada. (2015). Memorandum of Understanding between PulseNet USA and PulseNet Canada. Internal Document.
[69] S. P. Oliver, personal communication, August 3, 2017.
[70] Government of Canada. (2016). Genomics Research and Development Initiative: Antimicrobial Resistance. Mid-Year Performance Report for Shared Priority Projects Reporting period of 1 April 2016 to 30 September 2016.
[71] Public Health Agency of Canada. (2017). Division of Enteric Diseases Guelph Evaluation Overview. [Presentation].
[72] PHAC. (2017). Division of Enteric Diseases Guelph Overview – Food-borne Evaluation. [Presentation].
[73] Public health Agency of Canada. (2017). Performance Data Request – Evaluation of PHAC's Food-borne and Waterborne Enteric Illness. Internal Document.
[74] Public Health Agency of Canada. (2010). Food-borne Illness Outbreak Response Protocol (FIORP) 2010: To guide a multi-jurisdictional response. Retrieved from https://www.canada.ca/en/public-health/services/infectious-diseases/foodborne-waterborne-zoonotic-infections/illness-outbreak-response-protocol-fiorp-2010-guide-multi-jurisdictional-response.html.
[75] Public Health Agency of Canada. (2016). Public Health Notice: Outbreak of Hepatitis A infections; consumers advised not to eat Nature's Touch Organic Berry Cherry Blend frozen fruit. Retrieved from https://www.canada.ca/en/public-health/services/public-health-notices/2016/public-health-notice-outbreak-hepatitis-a-infections-consumers-advised-nature-s-touch-organic-berry-cherry-blend-frozen-fruit.html.
[76] Canadian Epidemiology Field Program Seminar. (October 17, 2017). Multi-provincial outbreak investigation of *E. coli* O121 associated with flour by Tanis Kershaw.
[77] Public Health Agency of Canada. (2017). Workforce Competencies: Learning Roadmaps for EC04 to EC07 Epidemiologists in the Food-borne Disease and Antimicrobial Resistance Surveillance Division.
[78] Health Canada and the Public Health Agency of Canada. (2016). Mobilizing Human Resources One HR for Science Working Group: Investing in People, Strengthening Our Workforce, Building Capacity. PowerPoint Presentation. Internal Document.
[79] Health Canada and the Public Health Agency of Canada. (2017). All Events Response Operations (AERO). Retrieved from http://mysource.hc-sc.gc.ca/eng/phac/about-phac/corporate-offices/health-security-infrastructure/all-events-response-operations-ae-1
[80] Health Canada and the Public Health Agency of Canada (2017). Health Portfolio Mobilization Strategy for Event Response. Retrieved from http://mysource.hc-sc.gc.ca/sites/default/files/health_portfolio_mobile-en.pdf
[81] Public Health Agency of Canada. (2017). Communication Triggers – Food-borne Illness Outbreak Events. Internal Document.
[82] Public Health Agency of Canada. (2017). Communication Triggers for Food-borne Illness Events Worksheet. Internal Document.
[83] Public Health Agency of Canada. (2017). Bilateral CFIA-PHAC Meeting. PowerPoint Presentation. Internal Document.
[84] Public Health Agency of Canada. (2017). Public Health Notice – Outbreak of E. coli infections linked to various flours and flour products. Retrieved from

https://www.canada.ca/en/public-health/services/public-health-notices/2017/public-health-notice-outbreak-e-coli-infections-linked-various-flours-flour-products.html
[85] Public Health Agency of Canada. (2017). Bilateral CFIA-PHAC Meeting. PowerPoint Presentation. Internal Document.
[86] Canadian Food Inspection Agency. (2017). Food Recall Warning – Janes brand frozen uncooked breaded chicken products recalled due to Salmonella. Retrieved from http://www.inspection.gc.ca/about-the-cfia/newsroom/food-recall-warnings/complete-listing/2017-10-17/eng/1508297726363/1508297729858
[87] La Vallée, J.C., and Charlebois, S. (20 November 2014). 2014 World Ranking: Food Safety Performance. Ottawa: Conference Board of Canada. Retrieved from: https://www.conferenceboard.ca/e-library/abstract.aspx?did=6562
[88] Government of Canada. (2016). Yearly food-borne illness estimates for Canada. Retrieved from https://www.canada.ca/en/public-health/services/food-borne-illness-canada/yearly-food-borne-illness-estimates-canada.html
[89] Pollari, F. and Public Health Agency of Canada. (2017). Trends of Human *Salmonella* Infections and of *Salmonella* Prevalence at Chicken Farm and Retail Level. PowerPoint Presentation. Internal Document.
[90] Public Health Agency of Canada. Public Health Agency of Canada Food Safety Strategic Plan 2013 – 2018. Internal Document.
[91] Murray, R., Glass-Kaastra ,S., Gardhouse, C., Mashall, B., Ciampa, N., Frankil, K., Hurst, M., Thomas, M.K., and Nesbitt. A. (September 14, 2017). "Canadian Consumer Food Safety Practices and Knowledge: Foodbook Study." Journal of Food Protection 80 (10), p. 1711–1718.
[92] Samadhin, M. and Public Health Agency of Canada. (2016). Canada's FoodBook: *How the government is using Canada's FoodBook, a national food consumption survey, to help identify foods most likely to cause food-borne illnesses, and improve outbreak response*. Internal document.
[93] Evaluation Directorate. Health Canada and Public Health Agency of Canada. (2014). Evaluation of the Food Safety and Nutrition Quality Program 1999-2000 to 2011-2012. Retrieved from https://www.canada.ca/content/dam/hc-sc/migration/hc-sc/ahc-asc/alt_formats/pdf/performance/eval/foodsafety-salubrite-eng.pdf
[94] Public Health Agency of Canada. (2015). National Enterics Surveillance Program (NESP) 2013 Annual Report Executive Summary. Retrieved from: https://www.nml-lnm.gc.ca/NESP-PNSME/surveillance-2013-eng.html
[95] Public Health Agency of Canada. (2015). National Enterics Surveillance Program. Retireved from: https://www.nml-lnm.gc.ca/NESP-PNSME/index-eng.htm
[96] Public Health Agency of Canada. (2017). *The Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS) 2015 Annual Report – Summary*. Retrieved from https://www.canada.ca/en/public-health/services/surveillance/canadian-integrated-program-antimicrobial-resistance-surveillance-cipars/2015-annual-report-summary.html
[97] Public Health Agency of Canada. (2017). *Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS) 2015 Annual Report.* Retrieved from: http://publications.gc.ca/collections/collection_2017/aspc-phac/HP2-4-2015-eng.pdf
[98] Public Health Agency of Canada. (2015). PulseNet – Overview. Retrieved from: https://www.nml-lnm.gc.ca/Pulsenet/overview-apercu-eng.htm

[99] Public Health Agency of Canada. (2015). PulseNet-Overview: Retrieved from: https://www.nml-lnm.gc.ca/Pulsenet/overview-apercu-eng.htm

[100] Public Health Agency of Canada. (2010) Food-borne Illness Outbreak Response Protocol: Annex 9 – Surveillance for Food-borne Illness. Retrieved from: https://www.canada.ca/en/public-health/services/infectious-diseases/food-borne-waterborne-zoonotic-infections/illness-outbreak-response-protocol-fiorp-2010-guide-multi-jurisdictional-response/annexes/annex-1-9.html#ann9

[101] Public Health Agency of Canada. (2010) Food-borne Illness Outbreak Response Protocol: Annex 9 – Surveillance for Food-borne Illness. Retrieved from: https://www.canada.ca/en/public-health/services/infectious-diseases/food-borne-waterborne-zoonotic-infections/illness-outbreak-response-protocol-fiorp-2010-guide-multi-jurisdictional-response/annexes/annex-1-9.html#ann9

[102] PHAC. (2017) *FoodNet Canada Short Report, 2015.* Retrieved from: http://publications.gc.ca/collections/collection_2017/aspc-phac/HP37-17-1-2015-eng.pdf

[103] Public Health Agency of Canada. *Overview FoodNet Canada (formerly known as C-EnterNet).* Retrieved from https://www.canada.ca/en/public-health/services/surveillance/foodnet-canada/overview.html

[104] PHAC. (2017) *FoodNet Canada Short Report, 2015.* Retrieved from: http://publications.gc.ca/collections/collection_2017/aspc-phac/HP37-17-1-2015-eng.pdf

[105] PHAC. (2017) *FoodNet Canada Short Report, 2015.* Retrieved from: http://publications.gc.ca/collections/collection_2017/aspc-phac/HP37-17-1-2015-eng.pdf

[106] Government of Canada. (2016). Genomics Research and Development Initiative: Antimicrobial Resistance – Mid-Year Performance Report for Shared Priority Projects. Reporting period of 1 April 2016 to 30 September 2016.

[107] Public Health Agency of Canada. Public Health Agency of Canada Food Safety Strategic Plan 2013 – 2018 – Progress Report 2015-2016. Internal Document.

[108] Hetman, BM., Mutschler, SK., Thomas, J.E., Gannon, V.P.J., Clark, C.G., Polari, F., and Tabooed, EN. (2017). The EpiQuant Framework for Computing Epidemiological Concordance of Microbial Subtyping Data. *Journal of Clinical Microbiology, 55*(5), 1334-1349.

[109] Government of Canada. (2016). Genomics Research and Development Initiative: Antimicrobial Resistance – Mid-Year Performance Report for Shared Priority Projects. Reporting period of 1 April 2016 to 30 September 2016.

[110] Galaxy User Website. Retrieved from https://usegalaxy.org/.

[111] PHAC. (2017). [Description of Galaxy users]. Internal document.

[112] IRIDA. (2018). IRIDA Documentation: Next-Generation Sequencing Data Storage, Management and Analysis. Retrieved from: https://irida.corefacility.ca/documentation/

[113] Marnier, E. (2017). *Neptune: A Bioinformatics Tool for Rapid Discovery of Genomic Variation in Bacterial Populations*. PowerPoint.

[114] Public Health Agency of Canada. PHAC Food Safety Strategic Plan – Progress Report – Fiscal Year 2015 – 2016. Internal Document.

[115] Public Health Agency of Canada. (2017). Division of Enteric Diseases Guelph Evaluation Overview. [Presentation]., p. 11 -12.

[116] Public Health Agency of Canada. (2 August 2017). *FoodNet Canada: Presentation to the President*. [Presentation].
[117] CIPARS. (2017) Canadian Integrated Program for Antimicrobial Resistance Surveillance Annual Report: 2015. [Forthcoming].