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Portrait of the Zoonoses Prioritized in 2015 by the Observatoire multipartite québécois sur les zoonoses et l'adaptation aux changements climatiques

Québec

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REPORT

Direction des risques biologiques et de la santé au travail

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Observatoire multipartite québécois sur les zoonoses et l'adaptation aux changements climatiques

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Foreword

The Observatoire multipartite québécois sur les zoonoses et l'adaptation aux changements climatiques (Observatoire) [Québec's multi-party observatory on zoonoses and adaptation to climate change] emerged from a partnership between the Institut national de santé publique du Québec (INSPQ) and Université de Montréal (UdeM). The Direction des risques biologiques et de la santé au travail (DRBST) of the INSPQ and the Groupe de recherche en épidémiologie des zoonoses et santé publique (GREZOSP) at the Faculté de médecine vétérinaire (FMV), UdeM, are the cornerstones for implementing and coordinating its initiatives and for affirming the One Health approach. It is crucial to recognize the efforts of the different bodies and individuals who have contributed to developing and consolidating the Observatoire.

A product of the collaboration between the Observatoire and external experts, this report presents a Québec portrait of the zoonoses prioritized in 2015 by the Observatoire. Knowledge about these zoonoses is synthesized in the form of fact sheets depicting their disease burden; existing surveillance, prevention and control measures; and the impact of climate change on both humans and animals. These fact sheets also point out associated knowledge gaps and challenges. The major strength of these fact sheets is that they synthetically document the current situation of these zoonoses in Québec, according to a One Health approach.

Producing this document required the contribution of many professionals from diverse settings with expertise in various fields, but all involved in working on issues related to the human-animal-environment interface. We would like to thank all the members and associates of the Observatoire for their contribution to developing this document.

Patricia Hudson, Scientific Director, Direction des risques biologiques et de la santé au travail, Institut national de santé publique du Québec

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Acronyms and Abbreviations

AOR	Agricultural Operations Regulation
BSV	Bureau de surveillance et vigie [Office of surveillance and vigilance]
CDC	Centers for Disease Control and Prevention
CFIA	Canadian Food Inspection Agency
CIPARS	Canadian Integrated Program for Antimicrobial Resistance Surveillance
CQSAS	Centre québécois sur la santé des animaux sauvages
DRBST	Direction des risques biologiques et de la santé au travail
DSP	Direction de santé publique
EEEV	Eastern equine encephalitis virus
EHEC	Enterohemorrhagic *Escherichia coli*
FMV	Faculté de médecine vétérinaire
GBS	Guillain-Barré syndrome
GREZOSP	Groupe de recherche en épidémiologie des zoonoses et santé publique
HC	Hospital centre
HUS	Hemolytic-uremic syndrome
INSPQ	Institut national de santé publique du Québec
InVS	Institut de veille sanitaire [Institute for Public Health Surveillance]
LSPQ	Laboratoire de santé publique du Québec
MADO	Maladie à déclaration obligatoire [reportable disease]
MAPAQ	Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec
MDDELCC	Ministère du Développement durable, de l'Environnement et de la Lutte aux changements climatiques
MFFP	Ministère des Forêts, de la Faune et des Parcs
MSSS	Ministère de la Santé et des Services sociaux
OIE	World Organization for Animal Health (formerly the Office International des Epizooties (OIE)
PCR	Polymerase chain reaction
PEP	Post-exposure prophylaxis
PHAC	Public Health Agency of Canada
RT-PCR	Reverse transcription polymerase chain reaction
TPP	Thrombotic thrombocytopenic purpura
UdeM	Université de Montréal
VTEC	Verotoxigenic *Escherichia coli*
WWPR	Water Withdrawal and Protection Regulation
WHO	World Health Organization
WNV	West Nile virus

Summary

In Québec, like elsewhere in the world, diseases that can be transmitted from animals to humans (zoonoses), which account for about 60% of diseases communicable to humans, are currently emerging. The complex dynamics of zoonoses can be affected by climate change. In response to this complexity, the Observatoire initiated a zoonosis prioritization approach in 2015 in the context of climate change. This approach allowed it to develop a portrait of zoonoses that will serve as the basis for documenting their evolving situations in Québec, in an effort to anticipate potential issues of concern. Documenting the zoonoses also allowed it to better identify the challenges and knowledge gaps specific to the prioritized zoonoses, thereby serving as a tool to direct and optimize zoonosis research, surveillance, prevention and control activities. Twelve zoonoses were prioritized: food-borne botulism in Nunavik, campylobacteriosis, cryptosporidiosis, eastern equine encephalitis, verotoxigenic *Escherichia coli*, Q fever, giardiasis, avian and swine influenza, Lyme disease, rabies, salmonellosis, and West Nile virus.

The prioritized zoonoses are documented in the form of a fact sheet for each of them, in a standardized data summary format, thus making this information more easily accessible to those using this report. The following information is presented for each zoonosis: number of human infection cases in Québec; disease burden in public health and animal health; transmission potential of the pathogen in question; link(s) to climate change; surveillance or early detection measures in Québec; prevention and control measures in Québec; other potential surveillance, prevention and control measures (elsewhere or recommended); and, lastly, associated knowledge gaps and challenges. The zoonosis documentation approach took place in two steps: (1) producing content for the fact sheets by synthesizing information derived from different sources (scientific articles, government reports, dissertations and theses); and (2) having experts validate and enrich the content, following an iterative process.

This exercise revealed the following main finding: given the current state of scientific knowledge, evidence-based data on the impact of climate change on zoonoses remain limited. This main finding deserves further consideration and refinement by the Observatoire.

1 Introduction

Around the world, zoonoses account for approximately 60% of diseases communicable to humans and 60% of emerging infections. They sicken around one billion people each year [1, 2]. In Québec, zoonotic diseases such as West Nile virus, Lyme disease and campylobacteriosis are responsible for hundreds of human cases reported each year (45, 153 and 2481, respectively, in 2015) (personal communication, Ministère de la Santé et des Services sociaux [MSSS], January 28, 2016). The dynamics of these infections are complex, often consisting of multiple reservoirs, vectors or modes of transmission that can be affected by climate change. This complexity requires a multi/interdisciplinary approach to properly respond to the public health challenges it represents.

In response to this complexity, the Observatoire was created in the fall of 2015. The primary mission of observatories is to collect, synthesize and compile knowledge in order to inform decision making and to facilitate access to information in a specific field. Jointly co-ordinated by the Institut national de santé publique du Québec (INSPQ) and the Faculté de médecine vétérinaire (FMV) at the Université de Montréal (UdeM), the Observatoire's general mandate is to facilitate the co-ordinated and centralized efforts of scientific experts and to produce an information synthesis in order to meet the needs of decision makers with respect to the effects of climate change on zoonoses and their possible adaptations. In particular, it provides an update on the evolution of zoonoses in Québec and on surveillance and research needs. As part of the work of this new provincial observatory, an approach to prioritizing zoonoses in the context of climate change was launched in 2015 with a view to directing research needs and zoonosis surveillance, prevention and control activities in Québec.

The primary objective of this report is to provide an initial portrait of the twelve zoonoses prioritized in 2015 for Québec and more specifically to document them and to highlight some of the existing challenges and knowledge gaps in terms of research, surveillance, prevention and control in the context of adaptation to climate change, in the form of a fact sheet for each zoonosis. This report is intended for people working in the field of zoonoses and those more generally involved in issues related to the human-animal-environment interface. It is not an exhaustive or systematic review of the prioritized zoonoses, but rather a synthesis of expert knowledge on the situation in Québec. The first part of this report presents the methodological aspects underpinning the prioritization and documentation of these zoonoses in Québec. The second part contains the fact sheets pertaining to each of the prioritized zoonoses.

2 Methodology for prioritizing and documenting the zoonoses

2.1 Methodology for the prioritization approach

2.1.1 Prioritization objectives

The zoonosis prioritization approach meets the need to direct: (1) research activities; and (2) surveillance, prevention and control activities in Québec. The ultimate aim is to minimize the impact of zoonoses on public health, especially by reducing their associated mortality and morbidity.

The objective of the approach carried out in 2015 was to prioritize the zoonoses of concern, for which a knowledge gap limiting public-health actions could be overcome by enhancing research, surveillance, prevention and control activities.

These zoonoses had to meet two inclusion criteria:

- They had to be currently present in Québec or in neighbouring Canadian provinces or U.S. states (defined by the documented presence of animal or human infection cases and by the documented presence of a reservoir or a competent vector for the pathogen in question); and
- Their incidence or emergence could be modulated by climate change, that is, the presence of a plausible link between the disease and anticipated climatological and meteorological conditions.

2.1.2 Prioritization steps

A working group was formed at the Observatoire to review the available literature and to draw up a preliminary list of zoonoses. This working group was composed of members and collaborators of the Observatoire: a representative from the Ministère de la Santé et des Services sociaux (MSSS), a representative from the Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (MAPAQ), a microbiologist and infectious disease specialist, a veterinarian, and the co-ordinator of the Observatoire at the INSPQ.

A brief literature review helped select the relevant literature for the approach. More specifically, the approaches of the Institut National de Veille Sanitaire (INVS) (France), the one proposed by Ng & Sargeant (Ontario, Canada) and that of the Centers for Disease Control and Prevention (CDC) (United States) were retained (Appendix 1). On the basis of these publications and the prioritization objectives, a preliminary list of 34 zoonoses was proposed by the working group to the members of the Observatoire (Appendix 2), who ranked them in order of importance, according to the concerns of each and of the organizations they represent, if any. Following this exercise, twelve zoonoses deemed priorities were selected.

2.2 Results of the prioritization approach

Following the prioritization exercise, twelve zoonoses were prioritized, including eleven reportable diseases (MADO) in Québec (neither avian nor swine influenza is a reportable disease):

- Avian and swine influenza;
- Campylobacteriosis;
- Cryptosporidiosis;
- Eastern equine encephalitis;
- Food-borne botulism;
- Giardiasis;
- Q fever;
- Lyme disease;
- Rabies;
- Salmonellosis;
- Verotoxigenic Escherichia coli;
- West Nile virus.

2.3 Methodology for the documentation approach

The prioritized zoonoses were each documented in the form of a fact sheet in order to:

- Have a standardized format for each zoonotic disease;
- Simplify access to information for the users of this report by means of a summary format;
- Facilitate the eventual development of a zoonosis prioritization tool linked to climate change.

The approach to documenting the zoonoses took place in two steps: (1) producing content for the fact sheets by synthesizing information from different sources (scientific articles, government reports, dissertations and theses); and (2) having experts validate and enrich the content, following an iterative process.

The fact sheets present information in the following order: disease burden in public health and animal health (Table 1); transmission potential (that is, animal to human [A-H], human to human [H-H], animal to animal [A-A], human to animal [H-A]); links to climate change (environmental factors with a documented or potential impact on the dynamics of the zoonosis); surveillance or early detection measures in Québec; prevention and control measures in Québec; and other potential surveillance, prevention and control measures. Each of the fact sheets ends with knowledge gaps and challenges.

Fact sheets on the prioritized zoonoses in the context of climate change

Food-borne botulism in Nunavik

Authors

Anne-Marie Lowe, Julie Picard

Pathogen: *Clostridium botulinum* toxin (in Nunavik, Type E causes 86% of outbreaks)

Primary animal reservoir in Nunavik: Seals

Table 1 Burden of botulism in public health and animal health

Prioritization criteria	Human	Animal
Symptoms or clinical signs/Severity/Morbidity	Rapid progression of symptoms: cranial nerves, neck, upper limbs, trunk and diaphragm, hands, legs; neurological sequelae (muscle fatigue, tremors; paralysis, suffocation). A small quantity of contaminated meat (teaspoon) is enough to poison someone	None
Duration	Symptom onset: 12–36 hours after ingestion of contaminated food (may extend up to 10 days).	
Lethality	Mortality rate of 16%–33%.	
Groups at risk of acquiring the infection and complications	Seal hunters: increased risk of contamination of marine mammal meat by environmental sources of *C. botulinum* type E during butchering operations along the southern coast of Ungava Bay (especially near large river mouths, owing to the high levels in these regions); people who eat fermented food.	Marine mammals (seals, whales, walruses), fish (salmon, salmon roe, other), land mammals (caribous, beavers)
Incidence over the past 5 years (Québec)	Rate/100,000 and 95% CI (Bureau de surveillance et vigie [BSV], MSSS, 2016) 2015: 0.06 (0.03-0.14) 2014: 0 2013: 0.01 (0-0.09) 2012: 0 2011: 0.02 (0.01-0.10) Average rate 2011–2014: 0.1 (0-0.03). Between 1990 and 2005: 82 cases reported and entered into the MADO registry in Québec, including 68 cases in Nunavik (4.3/yr). (1991–2000, Canada), average of 9 cases reported per year.	
Trend	The trend of botulism cases tends to follow the distribution of *C. botulinum* type E in sediments; from 1991 to 2000, an average of 9 cases were reported in Canada per year; half of the cases in Canada occurred in Nunavik, where the incidence is 1600 times higher than that in the rest of Canada; outbreaks mostly in the Arctic; since 1970, 90% of the outbreaks have occurred in the Ungava region[1, 2].	
Economic burden	Not measured in Québec.	
Social impacts	Highly sensitive issue because it is related to cultural practices involving the consumption of food rich in nutrients (iron, zinc, vitamins, omega-3).	

Transmission potential (A-H; H-H; A-A; H-A)

- A-H: Transmission through the consumption of fermented marine mammal meat (seal, walrus, beluga whales [3, 4]. Contamination of animals through sediments, sea water, coastal rock surfaces, fish, shellfish.
- H-H: Transmission through a common food source.
- A-A: N/A.
- H-A: N/A.

Link(s) to climate change: environmental factors with a documented or potential impact on the dynamics of this zoonosis

- Temperature: this pathogen and its toxin are sensitive to ambient temperature (they can develop at 4 °C)[5].

Surveillance or early detection measures in Québec

- Surveillance for human cases in Québec: cases reported to the MSSS as a disease subject to extreme surveillance by physicians and laboratories and entered into the MADO registry [Québec's reportable diseases registry].

Prevention and control measures in Québec

- Recommended preventive measures:
  - Precautions when handling marine mammal viscera;
  - Refrain from using containers made of plastic, glass, and plastic bags (replacing sealskin bags);
  - Education about fermentation methods, aimed at women and older adults;
  - Keep fermenting meat below 3 °C;
  - Boil marine mammal meat (challenge: non-acceptability).
- *Protocole Botulisme au Nunavik* (2007): intervention, treatment, investigation and identification of food contamination sources;
- Following diagnosis, supportive care: respiratory and nutritional, administration of antitoxins.

Other potential surveillance, prevention and control measures

Knowledge gaps

- Risk factors: identify high-risk meat-handling practices, while encouraging the preservation of cultural and traditional practices;
- Methods for the detection, prevention, control and treatment of temperature-sensitive infectious diseases.

Challenges

- Need to strengthen disease surveillance co-ordinated with the monitoring of climate data;
- Difficult to prevent;
- Economic: $4000/antitoxin dose; some cases require 3–4 doses;
- Feasibility: the Botulism Reference Service (BRS) for Canada is the only laboratory to perform the required analyses; delay in obtaining results.

Reference sources

Literature review on type E botulism (Horrowitz, 2010)[6]

Regional public health protocol on food-borne botulism[7]

"Flash-vigie," monthly news bulletin issued by the MSSS[8]

Report by the World Health Organization (WHO) on *Clostridium botulinum*[9]

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Campylobacteriosis

Authors

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Pathogen: *Campylobacter* spp. (heat-tolerant) – *C. jejuni* (90% of human cases), *C. coli* (7% of cases) and *C. lari*, *C. upsaliensis* or *C. fetus*. Epidemiology varies slightly by species.

Primary animal reservoir in Québec: Poultry (likely the main reservoir), cattle, swine, pets, and wildlife.

Table 2 Burden of campylobacteriosis in public health and animal health

Prioritization criteria	Human	Animal
Symptoms or clinical signs/Severity/Morbidity	Acute, sometimes severe, gastro-enteritis: liquid, abundant, and sometimes bloody diarrhea, severe abdominal cramps[1]. Possible chronic and severe sequelae: Reiter's syndrome, Guillain-Barré syndrome (GBS), erythema nodosum. Possible septicemia.	Generally asymptomatic in animal species (poultry, cattle, swine, dogs, cats, and wildlife): sometimes associated with diarrhea in young animals and in dogs and cats.
Duration	Generally from 1 to 7 days. May last longer, up to weeks, depending on severity.	Generally asymptomatic, otherwise diarrhea. Duration of shedding varies by animal species.
Lethality	Very low, mainly linked to auto-immune complications. Deaths occur predominantly in older adults or immunocompromised individuals.	Not documented.
Incidence over the past 5 years (Québec)	Rate/100,000 and 95% CI (BSV, MSSS, 2016): 2015: 29.91 (28.76-31.11) 2014: 35.63 (34.36-36.94) 2013: 34.27 (33.02-35.57) 2012: 32.05 (30,84-33.31) 2011: 28.24 (27.10-29.42) Average rate 2011–2014: 32.57 (31.96-33.20) *Frequent. The most frequently reported reportable bacterial enteric disease. Under-reported or under-diagnosed by a factor of 27[2].	High prevalence in certain types of farms: ▪ In Québec – 73% of dairy herds are positive[3]. In Canada – 43% of retail poultry are positive[4].
Groups at risk of acquiring the infection and complications	Vulnerable populations: children younger than 5 years, young adults, immunocompromised patients. Other risk factors: patients undergoing long-term proton pump inhibitor therapy, men (males). Workers in the poultry industry	▪ Animals at greater risk of being infected and contamination sources: reservoirs (poultry, cattle and swine), dogs, cats, and wildlife.

Table 2 Burden of campylobacteriosis in public health and animal health (cont'd)

Prioritization criteria	Human	Animal
Potential for causing outbreaks / Trends	Mostly sporadic cases (99% of reported cases). Possible outbreaks linked to consumption of contaminated water or food (raw milk, insufficiently cooked poultry meat or cross-contamination by poultry meat). Cases acquired during travel (about 20%). Cases acquired through direct contact with domestic or farm animals, and through swimming in recreational waters.	Endemic in poultry, cattle and pig farms Present in water and the cause of water-borne outbreaks.
Economic burden	Significant impact: costs linked to hospitalizations, especially to sequelae [5-7] (GBS), work absenteeism.	Variable, but generally low: farm management costs. Loss of revenue related to food recalls.
Social impacts	Low, not of great concern.	Low, but major public health concern for the industry. Presence of *Campylobacter* considered normal in most poultry farming, and also in poultry meat.

Transmission potential (A-H; H-H; A-A; H-A)

- A-H: contamination through animal products. Very low infectious dose, milk 15–22 cfu/L[8].
- H-H: negligible.
- A-A: very high (poultry, cattle, swine).
- H-A: N/A.

Link(s) to climate change: environmental factors with a documented or potential impact on the dynamics of this zoonosis

- Incidence rate associated with average weekly temperature, ambient temperature, humidity, extreme precipitation events.
- Clear seasonality for human incidence, peaking in summer; this remains unexplained.
- Possible drinking water contamination. Animals can also become colonized through water (e.g., beef-raising operations). The warmer the water is, the less *Campylobacter* can survive, unlike fecal coliform bacteria[9]. Frequent contamination of recreational waters, therefore possible impact of climate change through increased swimming activities.

Surveillance or early detection measures in Québec

- Surveillance for human cases: human cases reported to the MSSS by physicians and laboratories and entered into the MADO registry. Investigation by public health authorities in the event of an outbreak.
- Animal surveillance: Public health notices (MAPAQ).

Prevention and control measures in Québec

- Drinking water treatment plant.
- Food safety practices (restaurants, homes).
- General hygiene practices following contact with animals.
- MAPAQ investigation of dairy cattle, small ruminants and pets.
- Regulatory measures (Agricultural Operations Regulation [AOR], Water Withdrawal and Protection Regulation [WWPR],) and certifications (biological, CanadaGAP) governing manure and slurry management; agricultural advisory services (*services Agri-conseils*); *Prime-Vert* program; air chilling rather than water chilling for poultry; tighter controls in poultry slaughterhouses; and reorganization of practices to reduce contamination.
- Development of a federal strategy on farm-to-table risk management by the Joint Government-Industry Working Group on the Control of Salmonella and Campylobacter in Poultry.
- Preventive measures recommended by the MSSS and the MAPAQ regarding personal hygiene (hand washing), safe practices when handling and preserving food; environmental health and biosecurity.

Other potential surveillance, prevention and control measures

- Slaughterhouses: scheduled slaughter by batch status for *Campylobacter* (example of Denmark).
- Freezing by batch status for *Campylobacter* (example of Iceland).
- Surface pasteurization, irradiation of chicken parts?
- Awareness campaigns aimed at the most affected population groups (young adults, farm or slaughterhouse workers).
- Development of a standard for drinking water quality in relation to *Campylobacter*: avoid relying on indicators (fecal coliforms) that do not correlate with *Campylobacter*.
- Development of specific analyses for *Campylobacter* in water quality testing companies and for municipalities with vulnerable systems (e.g., surface wells).
- Reduction of salmonella and *Campylobacter* in poultry and farm-to-table poultry products (Health Canada).
- Genotypes involved to facilitate source attribution[10].

Knowledge gaps

- Exposure to contaminated poultry meat would explain around 40% of cases; the relative magnitude of the other suspected routes of transmission remains largely unknown.
- In Québec, the risk of campylobacteriosis associated, for example, with the contamination of recreational waters, direct contact with domestic animals, consumption of food crops (e.g., fruit and vegetables) contaminated by water is not very well documented and could be important.
- There is a lack of knowledge and documentation on risk factors.
- What proportion of the risk is associated with environmental or food exposure linked to manure and slurry management?
- What impact will the new biofood trends (biological, well-being) have on this risk?

Challenges

- Low level of public knowledge.
- Establishment of a FoodNet site in Québec to obtain an estimate of the risk.
- Underestimated infection because the acute form, although common, does not always require medical attention, but may lead to serious sequelae.
- In Ontario, the public health burden is greater than that for salmonellosis.
- The farm-to-table risk management approach (by animal production industries) contains many challenges associated with substantial knowledge gaps (documentation of critical points), but could be an approach with a positive impact.

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Cryptosporidiosis

Authors

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Pathogen: parasite -- *Cryptosporidium parvum* genotype 2. Other species of *Cryptosporidium* are zoonotic, but less common: *C. felis* (cat), *C. andersoni* (cattle), *C. ubiquitum* (deer), *C. canis* (dog), *C. melagridis* (poultry), *C. cuniculus* (rabbit), *C. serpentis and C. saurophilum* (reptiles). *C. hominis* (formerly *C. parvum* genotype 1) is generally transmitted between humans but can also be found in monkeys.

Primary animal reservoir in Québec: *C. parvum:* humans, cattle and other ruminants.

Table 3 Burden of cryptosporidiosis in public health and animal health

Prioritization criteria	Human	Animal
Symptoms or clinical signs/Severity/Morbidity	Moderate to severe diarrhea, abdominal cramps, nausea and headaches. According to immune status: chronic diarrhea, intestinal malabsorption, cholecystitis, death. In young children: repeat infections associated with growth deficiencies and cognitive delays.	Varies by etiological agent and infected animal. Abundant yellow watery diarrhea, weight loss, vomiting; Poults and chicks: signs of respiratory infection.
Duration	Symptom onset: from 2 to 25 days after infection, lasting from 1 to 2 weeks (even a month), depending on immune system.	Varies by etiological agent and infected animal.
Lethality	Higher lethality among immunocompromised individuals.	Higher lethality among young animals.
Groups at risk of acquiring the infection and complications	Immunocompromised individuals, people travelling/staying in endemic countries, swimmers in recreational water (water parks, pools), children in day care facilities, any person in close contact with livestock or their environment (e.g., veterinarians, farm and slaughterhouse workers).	Domestic livestock: mainly cattle but also sheep, goats and swine. Horses, cats, dogs and reptile are less commonly infected (varies by etiological agent). Young animals, especially calves, are particularly at risk of being infected, sick and shedders.
Incidence over the past 5 years (Québec)	Rate/100,000 and 95% CI (BSV, MSSS, 2016): 2015: 1.53 (1.29-1.82) 2014: 1.20 (0.99-1.47) 2013: 1.14 (0.93-1.40) 2012: 0.47 (0.34-0.65) 2011: 0.41 (0.29-0.58) Average rate 2011–2014: 0.81 (0.72-0.91) The increase over the years may be due to better laboratory detection (unknown under-reporting).	Prevalence: 88.7% of dairy farms in Québec positive [4].

Table 3 Burden of cryptosporidiosis in public health and animal health (cont'd)

Prioritization criteria	Human	Animal
Trend	Epidemic peaks in late summer and early fall	No documented or observed trend.
Economic burden	Not measured in Québec.	Significant for replacement cattle (young cattle) breeding.
Social impacts	Not of great concern.	Not significant.

Transmission potential (A-H; H-H; A-A; H-A)

- A-H: a small quantity of oocysts is enough for contamination: direct contact with the animals, their secretions or excretions; fecal-oral transmission; via contaminated food and water; particularly contamination by ingestion of water.
- H-H : fecal-oral transmission.
- A-A: fecal-oral transmission.
- H-A: fecal-oral transmission.

Link(s) to climate change: environmental factors with a documented or potential impact on the dynamics of this zoonosis

- Temperature: positive associations (United Kingdom, United States and New Zealand: differences between rural and metropolitan areas possibly due to greater exposure to animals)[5] including seasonality (increase in cryptosporidiosis cases during the summer, which is believed to be linked to the greater use of recreational waters) and negative associations (New Zealand: increase in temperature negatively associated with the number of cases[6]). The magnitude of climate effects on incidence would depend on local ecological and demographic factors[7].
- Precipitation: positive association between the increase in the frequency, intensity and duration of precipitation (extreme climate events leading to overflowing sewer systems and flooding) and the number of cases reported[6].
- Change in agricultural land use (density of cattle by territory and farm, ratio of farms to humans; proportion of land where manure is applied); agricultural land use patterns could influence pathogen load by altering the distribution of infectious and vulnerable hosts and by modifying the routes of transmission[7].

Surveillance or early detection measures in Québec

- Surveillance for human cases: cases reported to regional public health authorities by physicians and laboratories and entered into the MADO registry.
- Cryptosporidiosis surveillance program currently underway (until the spring of 2018) at the Laboratoire de santé publique du Québec (LSPQ) to enhance the epidemiology of cryptosporidiosis in Québec (circulating strains regionally and provincially), and to identify the acquisition risk factors and the virulence factors of specific subtypes.

Prevention and control measures in Québec

- Québec's Regulation Respecting the Quality of Drinking Water (section 5.1)[8]: water filtration plants use criteria based on log removal of parasites (*Giardia* and *Cryptosporidium*). Treatment intensity depends on the concentration of the indicators used (*E. coli*, total coliforms) to evaluate the microbiological quality of their water (source water and drinking water). In Québec, unlike other jurisdictions, especially the United States, plants do not test for the presence/absence of *Cryptosporidium* oocysts.
- *Guidelines for Canadian Drinking Water Quality*: when the presence of cysts or oocysts infectious to humans is suspected or established (during environmental surveillance), or if *Giardia* or *Cryptosporidium* are found to be responsible for infectious water-borne outbreaks in a community, a special program for the treatment and distribution of drinking water must be implemented, along with a watershed and wellhead protection plan (where feasible) or other measures designed to reduce the risk of illness.
- Regulatory measures (AOR, WWPR), and certifications (biological, CanadaGAP) governing manure and slurry management, along with the support provided by agricultural advisory services (services *Agri-conseils*) and the *Prime-Vert* program.
- Preventive practices recommended by the MAPAQ and the MSSS regarding hand hygiene after handling animals or working in a barn or in a child daycare centre. Wash garden vegetables before eating them. Avoid drinking untreated water (lakes, streams, rivers). Public swimming pools: shower before getting into the pool; exclude people with diarrhea, and ban food consumption on site.
- Recommended preventive measures associated with animal environment hygiene.
- Control: drinking water filtration and disinfection; boil water for at least one minute; find an alternative water source or use bottled water; parasite inactivation by freezing (–22 °C for ten or more days) or by heat (65 °C for two or more minutes).
- Supportive care based on rehydration. Medical care for severe cases (especially for immunocompromised individuals).

Other potential surveillance, prevention and control measures

- A protozoan pre-screening step in water distribution systems helps identify the water sources that are particularly vulnerable to contamination by this type of pathogen[9].
- Take into account the nature of the problem potentially causing the presence of oocysts: quality of raw water (proximity to farm land), performance of water treatment equipment and components, and some particular climatological events (e.g., flooding).
- In case of an outbreak: increase public health messages focussing on prevention through hand washing and good practices to avoid fecal-oral contamination.
- Ultraviolet treatment may be used in the absence of filtration.

Knowledge gaps

- Limited knowledge about the epidemiology of cryptosporidiosis in Québec. In May 2013, an outbreak of diarrhea caused by *C. hominis* was identified in Nunavik, with an annual incidence of 420/100,000 population. In this case, anthropogenic transmission was more plausible than zoonotic transmission. Nevertheless, this outbreak of cryptosporidiosis highlighted the potential impact of this infection on children younger than five years, who were particularly affected by this parasite (incidence of 1290/100,000 population). Cryptosporidiosis is associated with potential effects on children's physical and cognitive development[1].

Challenges

- Risk analysis is complex given the difficulty with detecting oocysts in drinking water and the lack of an adequate risk assessment indicator (lack of correlation between total coliform and E. coli tests conducted to test water quality and to test for the presence or absence of Cryptosporidium).
- Environmental factors documented as having an impact on the dynamics of cryptosporidiosis should be taken into account when planning public health responses to ecological risks and when developing policies involving climate change.
- A rise in ambient temperature could be an early warning sign to intensify preventive efforts, including education for swimming pool users, regarding Cryptosporidium infections, which could rise in number, given the projected increase in temperatures resulting from climate change.
- Variability in municipalities' drinking water filtration performance levels could be an issue in a context of climate change: municipalities using surface water are legally obligated to use filtration, but Québec still has some small systems (under 200 persons) without filtration and whose fecal contamination indicators are fecal coliforms or *Escherichia coli*. The lack of filtration in a water treatment system (e.g., small surface water systems without filtration) can lead to water contamination by *Cryptosporidium*, especially through the waste of infected animals and can cause an outbreak such as the one documented in 2013 in Baker City, Oregon, (community attack rate: 28.3% [95% CI 22.1-33.6%], 2780 affected individuals)[2].
- Difficulty with enforcing preventive measures in public pools and public resistance to applying these measures (e.g., showering before entering a pool, excluding people with diarrhea).
- The parasite is resistant to the chlorine concentrations used in swimming pools (contact time necessary to kill the parasite: 10.6 days at 1 mg/L)[3].
- Issue of good agricultural practices linked to land fertilization with potentially contaminated manure or slurry (potential for runoff into waterways).
- Underdiagnosis of infection: without a specific medical prescription, screening for Cryptosporidium oocysts is not performed during conventional stool parasite tests (the standard method of testing for parasites does not detect them). In addition, wide variability exists in laboratory screening modalities. The new PCR-based methods for parasite detection recently introduced in some hospitals will possibly shed light on the reality of the underdiagnosis of this parasitic infection over the next few years. Microscopy for oocyst detection requires experienced personnel.
- Importance of preventing cryptosporidiosis, given (a) the lack of treatment approved by Health Canada, (b) the fact that infected individuals can shed oocysts for months without presenting with symptoms, and (c) oocyst resistance to disinfection.

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Eastern equine encephalitis

Authors

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Pathogen: Eastern equine encephalitis virus (EEEV)

Primary animal reservoir in Québec: Wild birds (i.e., passerines/perching birds)

Primary vector in Québec: *Culiseta melanura*

Table 4 Burden of EEEV in public health and animal health

Prioritization criteria	Human	Animal
Symptoms or clinical signs/Severity/Morbidity	Febrile syndrome (fever, myalgia, arthralgia), followed a few days later by symptoms of meningo-encephalitis, which may be sudden and severe (headaches, behaviour changes, severe convulsions, coma). Meningo-encephalitis may progress to death or survival with severe neurological sequelae (generally more severe than those of West Nile virus (WNV))[3].	Generally asymptomatic, but severity varies by affected species: Horses: fever, anorexia, depression, meningo-encephalitis. Wild birds (amplification hosts): normally asymptomatic. Affected domestic birds: pheasants, quails, ducks, turkeys, emus. Other susceptible species: llamas, alpacas.
Duration	1–2 weeks	1–2 weeks, but usually 24–48 hours.
Lethality	30%–70%	75%–90% of horses presenting with nerve signs die within 1 to 5 days.
Incidence over the past 5 years (Québec)	Rate/100,000 and 95% CI (BSV, MSSS, 2016): 2015: 0 2014: 0 2013: 0 2012: 0 2011: 0 Average rate 2011–2014: 0 Seroprevalence: no seropositive individuals among 485 humans tested in southern Québec in 2014.	43 equine cases from 2008 to 2010, along with a herd of infected emus each of those years[4].The preceding equine cases were isolated cases (1972, 1999) and the following were sporadic cases.
Groups at risk of acquiring the infection and complications	Vulnerable groups: individuals younger than 15 years and older than 55 years. Environmental risk is higher near swampy areas (habitat of the *Culiseta melanura* mosquito).	Avian reservoir (e.g., passerines). Horses, pheasants, quails, ducks, turkeys, emus, llamas, alpacas, deer[5].

Table 4 Burden of EEEV in public health and animal health (cont'd)

Prioritization criteria	Human	Animal
Potential for causing outbreaks / Disease trend	Not measurable (diagnostic tests rarely performed). Most serological results for the diagnosis of EEEV are negative.	Outbreaks in horses between 2008 and 2010. Sporadic equine cases from 2011 to 2015. Seroprevalence of 6%–8% in southern Québec among horses, higher near probable endemic areas.
Economic burden	Not measured in Québec. Per-patient economic burden evaluated in the U.S., especially in the northeastern states[6].	Not measured in Québec. Limited to owners of susceptible animals. Economic burden evaluated among horses in Florida[7].
Social impacts	Small-scale perception of a major threat, and significant local media impact in affected in eastern U.S. communities[8].	Sometimes of concern to owners because of significant and rapid mortality.

Transmission potential (A-H; H-H; A-A; H-A)

- A-H: Vector transmission following a bite from a mosquito infected by an animal reservoir host. Risk of non-vector transmission: through contact (aerosols or indirect) with the blood or tissue of infected animals (e.g., laboratory staff, hunters removing deer antlers[5]). www.canada.ca/en/public-health/services/laboratory-biosafety-biosecurity/pathogen-safety-data-sheets-risk-assessment/eastern-equine-encephalitis.html.
- A-H: Vector transmission following the bite of a mosquito infected by an animal reservoir host.
- H-A: N/A.
- H-A: N/A.

Link(s) to climate change: environmental factors with a documented or potential impact on the dynamics of this zoonosis

- EEEV activity seems to have been migrating north for the past ten or so years[9].
- The impact of climate change on the enzootic amplification cycle is difficult to predict in terms of the time and location of outbreaks (no outbreak prediction, variable).

Surveillance or early detection measures in Québec

- Surveillance for human cases: cases reported by physicians and laboratories and entered into the MADO registry.
- Surveillance for animal cases: Cases reported to the MAPAQ by laboratories, and investigations by the MAPAQ, which transmits the information to public health authorities. Immediately notifiable disease by laboratories to the Canadian Food Inspection Agency (CFIA).
- Passive surveillance for laboratory-confirmed human cases.
- Animal surveillance via clinical equine cases. Equine vaccination seems very widespread in southern Québec. This limits the sensitivity of equine case surveillance. Surveillance based on sentinel domestic birds would provide an untimely alert with regard to human cases.
- Entomological surveillance identified positive vectors in the south of the Lanaudière region in 2009-2010 (https://www.agrireseau.net/documents?id=80373).

Prevention and control measures in Québec

- Equine vaccination available.
- Real-time communication of animal surveillance data (number of cases per region).
- Communications to enhance the vigilance of equine veterinarians early in the season: recommendation to vaccinate horses.
- Communications regarding individual preventive measures to avoid mosquito bites (although targeted toward WNV), in both humans and susceptible animals.
- No human vaccine widely available. A vaccine has been developed for laboratory staff.
- Given that the primary enzootic vector lays eggs primarily in marshes; the application of larvicides and adulticides must target natural environments. Larvicides-adulticides are occasionally applied in the U.S. during outbreaks (not done in Québec).

Knowledge gaps

- The role of other vectors such as bridge vectors needs to be clarified (potential role of the following species: Coquilletidia perturbans, Culex pipiens (Cx pipiens), Cx restuans, Cx erraticus, Cx salinarius, Ochlerotatus canadensis (Och. canadensis), Och sollicitans, Och triseriatus, Och sticticus, Och japonicus, Och atropalpus, Aedes vexans, Anopheles punctipennis, Culiseta morsitans).
- Impact of climate change on the spatio-temporal distribution of EEEV cases. Effect of climate change on the extrinsic incubation period (EIP) of approximately three days. Impact of climate change on vector dispersion areas (primary and secondary).
- Lack of data on the prevalence of EEEV in avian reservoir species.

  Which elements contribute to maintaining the epidemiological cycle of EEEV, other than the presence of a swamp or bog: the presence of reptiles or amphibians as was documented in the U.S.[1,2]? This knowledge would contribute to improving risk prediction.

Challenges

- Possible underreporting and underdiagnosis of EEEV.
- The proportion of idiopathic encephalitides potentially caused by the EEEV or by the California serogroup encephalitis virus or other types of viral encephalitides present in Québec remains unknown.
- In 2014–2015, ten or so human cases were reported in neighbouring U.S. states.
- Primary care physicians or specialists are likely not very aware of this risk. Which criterion should trigger communications to increase their vigilance and to support the diagnostic process? The confirmation of equine cases in a region may be one (it is sometimes one for public health authorities). Development of a decision tree algorithm to perform diagnostic tests.
- Laboratory capacity to perform routine tests for the arboviruses present in Québec during the mosquito season.
- It was found that pathogen detection aimed at determining the infectious etiology of a case of viral encephalitis was primarily carried out for the *Herpes simplex* virus, given the availability of an antiviral treatment. Intensified communications were carried out among neurologists in order to emphasize the importance of detecting WNV in cases of encephalitis, meningitis and meningo-encephalitis during the WNV season. However, those communications did not include other arboviruses, such as EEEV or the California group of encephalitis viruses.
- Paired sera are usually required for diagnosis in humans. In animals, usually performed by PCR on the brain at the time of necropsies. Difficult to diagnose with reverse transcription-polymerase chain reaction (RT-PCR), owing to short viremias and few virions in the cerebrospinal fluid.
- No treatment available. Supportive care.
- The animal cases reported to the MAPAQ are often associated with other cases (suspected or confirmed) in the surroundings of the affected municipality. Recurring outbreaks in animals in the Lanoraie-Lavaltrie region between 2008 and 2010, and phylogenetic analyses suggest that the virus overwinters there.
- Surveillance capacity via sentinel animals.
- Entomological surveillance programs in place in Québec likely have limited capacity to sensitively detect the transmission risk of arboviruses other than the WNV because they do not target environments favourable to them.
- The impact of mosquito control programs on the risk of EEEV infection is to be evaluated.

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Verotoxigenic *Escherichia coli*

Authors

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Pathogen: bacterium, *Escherichia* coli O157:H7 and other enterohemorrhagic (Shiga toxin-producing) strains (EHEC).

Primary animal reservoir in Québec: cattle, other ruminant mammals or herbivores.

Table 5 Burden of verotoxigenic *E. coli* infections in public health and animal health

Prioritization criteria	Human	Animal
Symptoms/Severity/ Morbidity	Variable symptoms: gastroenteritis with diarrhea, severe abdominal pain, mild fever. May progress to bloody diarrhea in 50% of cases. May progress to hemolytic-uremic syndrome (HUS) in 5%–15% of cases: HUS includes hemolytic anemia, thrombocytopenia and kidney failure. May progress to thrombotic thrombocytopenic purpura (TTP), especially in older adults. One third of the cases of enterohemorrhagic *E. coli* (EHEC) infection requires hospitalization[1-3]. HUS can leave serious sequelae, such as kidney failure.	Symptoms vary by *E. coli* strain and animal. More severe in young animals (especially cattle, swine, sheep, horses): diarrhea, sometimes associated with septicemia and high mortality, generally among newborn calves and piglets. However, strains causing illness in calves and possibly in other animal reservoirs of verotoxigenic *E. coli,* generally differ from those that infect humans. Verotoxigenic *E. coli* is not associated with the presence of clinical signs in calves[4].
Duration	Variable. If HUS appears, it usually develops within 2 weeks of the onset of diarrhea. Contagiousness persists as long as the bacteria is present in the stools.	In cattle, intermittent shedding generally lasting from 1 to 3 months, often triggered by stress. Seasonal shedding is greater at the end of summer[5].
Lethality	Lethality: around 1%. If HUS: 5%.	Cattle: morbidity and lethality vary by type of farm operation (up to 75% and 50%, respectively), but are associated with strains other than verotoxigenic *E. coli*.
Groups at risk of acquiring the infection and complications	Children in daycare facilities, people in contact with farm animals. HUS: children younger than 5 years (proportion of HUS among those younger than 5 years: 15%).	Cattle are recognized as a significant reservoir of *E. coli*, especially verotoxigenic *E. coli.* Some cattle ("super shedders") in a herd may be alone responsible for a major part of the shedding in the herd[6]. Sheep, goats and swine, can also shed strains of verotoxigenic *E. coli.*

Table 5 Burden of Verotoxigenic *E. coli* infections in public health and animal health (cont'd)

Prioritization criteria	Human	Animal
Incidence over the past 5 years	EHEC infection rates have been relatively stable since 2011, ranging from 1.06 to 1.34 per 100,000 in Québec. Rate/100,000 and 95% CI (BSV, MSSS, 2016): 2015: 1.25 (1.04-1.52) 2014: 1.01 (0.81-1.25) 2013: 1.21 (1.00-1.48) 2012: 1.34 (1,11-1.61) 2011: 1.06 (0.86-1.31) Average rate 2011–2014: 1.15 (1.04-1.28) The number of annual cases during the same period ranged from 76 to 108 per year.	The prevalence of *E. coli* 0157 in the feces of North-American cattle is 10.68% (95% CI: 9.17–12.28%), in feeder cattle; 4.65% (95% CI: 3.37–-6.10%) in adult beef cattle, and 1.79% (95% CI: 1.20–2.48%) in adult dairy cattle[5].
Trend	Decreasing incidence in Québec since 2000, possibly linked to better public education concerning the handling and consumption of ground meat. Downward trend in the number of cases in Canada: *E. coli* incidence rates from 2003 to 2013 reported under the National Enteric Surveillance Program (NESP) of the Public Health Agency of Canada (PHAC), show that, in 2012, there were approximately two times fewer reports of *E. coli* 0157 than in 2006.	Emergence of new *E. coli* strains associated with virulence variability and vaccination response. In cattle, the prevalence of *E. coli* increases with the density of the population in a cattle operation. Increase in *E. coli* resistance to certain category 1 antibiotics, observed under the *Programme québécois d'antibiosurveillance vétérinaire*[7] [[Québec's veterinary antimicrobial resistance surveillance program]. However, in the chickens on farms, at slaughter (abattoir) and at the grocery store (retail) sampled under the Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS), a decreasing resistance to third generation cephalosporins (category 1 antibiotics) was identified between 2013 and 2014. This decrease is associated with the elimination of the preventive use of category 1 antibiotics in chickens, a compulsory measure under the Chicken Farmers of Canada's On-Farm Food Safety Assurance Program since May 15, 2014.

Table 5 Burden of verotoxigenic *E. coli* infections in public health and animal health (cont'd)

Prioritization criteria	Human	Animal
Economic burden	Significant. EHEC infection outbreaks have been reported over the past few years, and different products, beef and others, have been identified as the food vehicles. Costs associated with hospitalizations, long-term sequelae and work absenteeism.	Significant for pig farming. Significant for replacement cattle farming (young cattle), but associated with strains other than verotoxigenic *E. coli* strains. Loss of revenue linked to food recalls.
Social impacts	Significant. Long-term sequelae in cases that developed complications following infection, need for specialized care (50% of patients with HUS will need dialysis).	Low, but industry concern for public health. Presence of *E. coli* considered normal in cattle farming, as well as in their meat.

Transmission potential (A-H; H-H; A-A; H-A)

- A-H: Indirectly through the ingestion of contaminated food (improperly cooked beef, unpasteurized milk, other contaminated foods), through vegetable contamination (e.g., contaminant passes through the roots or may affect the vegetable itself following the application of manure), and through drinking water and recreational water. Through direct contact with farm or zoo animals or through contact with their environments, especially in agritourism activities. The bacterium's survival in the environment depends on the serotype, ranging from several months on food or in the soil to even several years in excrement.
- H-H: Fecal-oral transmission (at-risk group: children in daycare facilities).
- H-A : Fecal-oral transmission
- A-A : Fecal-oral transmission

Link(s) to climate change: environmental factors with a documented or potential impact on the dynamics of this zoonosis

- Temperature: during the hottest months of the summer, the prevalence increases enough to rank *E. coli* 0157:H7 infections as a leading gastro-intestinal infection. In addition, shedding in cattle is greater in summer[8].
- Precipitation: soil and water contamination linked to the application of manure/slurry from the spring to the fall, or to municipal wastewater overflows. Increased risk of water-borne contamination for certain types of more vulnerable soils, especially during heavy rains. Some types of soils are already considered to be more vulnerable to bacterial contamination.

Surveillance or early detection measures in Québec

- Surveillance for human cases: cases reported to regional public health authorities by physicians (HUS and TTP) and by laboratories (EHEC, HUS and TTP) and entered into the MADO registry. Laboratory-based surveillance for *E. coli* O157 is performed in Québec through hospital laboratories and the LSPQ. From 2011 to 2016, only the Ste-Justine Hospital laboratory ran tests for the other serotypes in all patients providing stool samples for infectious diarrhea. Early diagnosis in infants and children attending daycare services promotes the prevention of EHEC infections, interrupts their spread and facilitates the management of HUS in order to minimize the impact of verotoxigenic *E. coli*. Since September 12, 2016, the detection of Shiga toxin-producing *E. coli*, other than O157, has been performed by all medical microbiology laboratories in Québec, on bloody stools, in children younger than five years with diarrhea and upon medical prescription following suspicion. The wider availability of the test may have contributed to increasing the number of reported cases of verotoxigenic *E. coli* in 2016 and subsequent years.
- Active *E. coli* surveillance programs in slaughterhouses.

Prevention and control measures in Québec

- Control measure in slaughterhouses, especially steam pasteurization in certain slaughterhouses.
- Québec's veterinary antimicrobial resistance surveillance program and compulsory continuing education for veterinarians on the use of antibiotics.
- Preventive measures recommended by the MSSS and the MAPAQ: personal hygiene (hand washing), safe practices for handling, preserving and cooking food, particularly ground beef; environmental hygiene and biosecurity.
- Regulatory measures (AOR and WWPR), and certifications (biological, CanadaCAP) governing manure and slurry management, along with the support provided by agricultural advisory services (*services Agri-conseils)* and the *Prime-Vert* program.
- Recommendations on the management, maintenance and periodic testing of private drinking water wells,
- Humans: cleanliness and personal hygiene; sanitation services; protection of food products; milk pasteurization; meat inspection; preventive measures in healthcare facilities.
- Animals: diet favouring good immunity of young animals (feeding colostrum to calves and reducing post-weaning stress in piglets), vaccination of animals during episodes of diseases associated with *E. coli*, but does not specifically target verotoxigenic strains.
- Supportive care for human cases (generally refraining from antibiotic therapy for humans, because of lack of proven benefit and potentially increased risk of complication).
- Supportive treatment and antibiotic therapy for animal cases, where needed.

Other potential surveillance, prevention and control measures

- Farm-to-table control efforts: include vaccinating calves with colonization factors, and use of new antibiotics (e.g., bacteriocins, chloral hydrate, bacteriophages, other).
- Other barrier methods exist elsewhere and can be implemented in slaughterhouses and food-processing industries, such as steam pasteurization and irradiation.

Knowledge gaps

- Develop knowledge about the interface of humans and food/water contaminated by manure to better understand the risk of this contamination:
  - What fraction of the risk is associated with environmental or food exposure linked to manure and slurry management (vs municipal wastewater, for example)?
  - What impact will the Québec Policy on Residual Materials have on the risk associated with environmental or food exposure?
- The farm-to-table risk management approach (by animal production industries) contains many challenges associated with substantial knowledge gaps (documentation of critical points), but could be the most effective approach.

Challenges

- Concerning good agricultural practices regarding manure or slurry fertilization (potential for runoff into waterways):
  - What impact will the new biofood trends (biological, well-being) have on this risk?
- Consumer education, including staff who handle food.
- A portrait of serotypes is available for animals in Québec, but only partially for humans (e.g. : surveillance for the other serotypes by the Ste-Justine university hospital shows that they are three times more prevalent than the O157 serotype); diagnostic evidence for the other strains is lacking.
- While some measures help decrease shedding by cattle (e.g., vaccination), the economic benefits do not encourage investments by producers in that regard. It could be strategic to prioritize interventions aimed at "super shedders."

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Q fever

Authors

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Pathogen: *Coxiella burnetii*

Primary animal reservoir in Québec: domestic ruminants (sheep, goats, cattle). Several other species may be infected (rodents, cats, ticks).

Table 6 Table 6 Burden of Q fever in public health and animal health

Prioritization criteria	Human	Animal
Symptoms or clinical signs/Severity/Morbidity	Most cases are asymptomatic or present with flu-like syndrome[1]. Complications: hepatitis, pulmonary diseases, meningo-encephalitis. Chronic disease: Endocarditis (very difficult to treat), vascular infection, pregnancy disruption (miscarriage, fetal death, premature labour).	Goats and sheep are most often infected (perhaps because they shed the bacterium in large amounts during parturition). Generally asymptomatic. Acute stage: respiratory problems, febrile syndrome. Chronic stage: reproductive problems (abortion, still births, weakly offspring).
Duration	7 to 14 days, except if complications. Incubation period varies by infectious dose, but generally 2 to 3 weeks for acute infection.	Acute stage: 48 hours to 3 weeks. Chronic stage: months.
Lethality	Low mortality (1% in untreated patients) in the acute stage – abortion. Mortality rate is 9% in patients with endocarditis, which is a potentially fatal infection if untreated. Diagnosis and early treatment of Q fever is the method of prevention[2].	Moderate to high (in goats and sheep, sometimes causes abortion crises).
Incidence over the past 5 years (Québec)	Incidence rate of cases reported to Québec – Rate/100,000 and 95% CI (BSV, MSSS, 2016): 2015: 0.37 (0.26-0.53) 2014: 0.19 (0.12-0.32) 2013: 0.42 (0.30-0.58) 2012: 0.46 (0.33-0.63) 2011: 0.54 (0.40-0.72) Average rate 2011–2014: 0.40 (0.34-0.48)	No trend identified. Seroprevalence: 45% of dairy cattle herds, 71% of sheep herds are positive, cats 19%–24% Seroprevalence in Ontario (proportion of herds with at least one seropositive animal[3, 4]): ▪ Meat sheep: 42% ▪ Dairy sheep; 64% ▪ Meat goats: 44% Dairy goats: 79%

Table 6 Burden of Q fever in public health and animal health (cont'd)

Prioritization criteria	Human	Animal
Groups at risk of acquiring the infection and complications	Vulnerable populations: ▪ Immunocompromised individuals (older adults, patients undergoing chemotherapy, those with chronic diseases) patients with valvular heart disease or vascular abnormalities, pregnant women; ▪ Veterinarians, farm and slaughterhouse workers exposed to reservoir species (especially sheep, goats); ▪ People residing near goat or sheep farms[5,6].	Most species can be infected: domestic ruminants, cats, rodents and lagomorphs are the most commonly involved in contamination in humans[7, 8].
Potential for causing outbreaks	Severe outbreak, with 92 confirmed and 23 probable cases, associated with an Easter petting zoo in two malls in the Montérégie region in 1999[9]. Potential outbreak for people living near small-ruminant farms (aerosol dispersion). Wind is an important abiotic factor, which contributes to propagating desiccated contaminated particles into the atmosphere especially during the application of contaminated manure or following the parturition season[10].	Currently endemic. Outbreaks associated with goats and sheep. Potential role of rodents in the dispersion of contaminated dust particles.
Economic burden	Not measured. Costs incurred for the diagnosis and treatment of diseases in the acute stage are sometimes greater than those for other infections, given that the investigation focuses on multiple etiologies. Direct and indirect costs for chronic infection (endocarditis, vasculitis) are higher owing in particular to extended antibiotic treatments (more than 12 to 18 months) and its associated health impairment. Preventive measures at the provincial level to reduce the risk to pregnant workers (cf. the program, For a Safe Maternity Experience)[11].	Low.
Social impacts	Low impact among the public (knowledge, perception). Rare cases of chronic disease, but major impact on patients and their families[12].	Significant impacts: Concern in the domestic ruminant industries among domestic ruminant farmers and associated partners.

Transmission potential (A-H; H-H; A-A; H-A)

- A-H: High. Increased risk of transmission during peripartum period – via contaminated soil, air, animal products (raw milk, sheep manure) – Transmission by aerosols with very low infectious dose[13].Very low infectious dose (seroconversion following inoculation with as few as 2–4 bacteria[14], whereas shedding may be very high in the peripartum period. Other possible, but uncommon, modes of transmission are: iatrogenic transmission (alternative medicine) by injections of sheep fetal cells in Germany in 1997 and 2014[15]. Survival up to several months in the environment and on the wool. May be found for several weeks in the air around a farm after an abortion. Transmission risk through ingestion of raw milk or the milk products of infected ruminants. The endospores are highly resistant to the action of some chemical disinfectants and to heat, high osmotic pressure, desiccation and ultraviolet radiation. The placenta of animals that abort may contain up to 1×10^9 bacteria per gram of tissue, which represents a significant source of environmental contamination[16]. They may therefore survive for several months when shed by the host into the environment[17].
- H-H: Rare by placental transmission, blood transfusion, bone marrow graft, sexual transmission.
- A-A : High. Increased transmission risk during peripartum period via aerosols or droplets or ingestion (accumulation in tissues and liquids -- uterus, placenta, mammary glands, birthing fluids, milk, sexual transmission).
- H-A: N/A

Link(s) to climate change: environmental factors with a documented or potential impact on the dynamics of this zoonosis

- Drought or increased winds may promote the dispersion of contaminated aerosols. Risk of transmission between flocks is linked to landscaping features and meteorological conditions (drought, winds).
- Soil contamination – high resistance in the environment. The manure of infected animals may act as a contamination source if it is not managed properly. Proper management of excretions, which may be influenced by climate conditions.

Surveillance or early detection measures in Québec

- Surveillance for human cases: cases reported to the regional public health authorities by physicians and laboratories and entered into the MADO registry. Reported human cases are primarily acute cases. The nosological definition does not target cases affected by the chronic form.
- Surveillance for animal cases: cases reported to the MAPAQ by laboratories, and investigations conducted by the MAPAQ.

Prevention and control measures in Québec

- Basic hygiene measures during direct or indirect contact with animal reservoir species are recommended to minimize infection risks, along with measures related to birthing and manure management[18]. Recommendations disseminated yearly (before Easter) to petting zoo owners and suppliers or to agritourism activity managers, aimed at preventing health and safety risks, particularly the exclusion of animals potentially at risk of transmitting the infection in public events.

Other potential surveillance, prevention and control measures

- Vaccination for workers (no vaccine is currently approved in Canada).
- Vaccination for farm animals (i.e., small ruminants).

Knowledge gaps

- Low level of public knowledge.
- Level of scientific knowledge about transmission dynamics: moderate.
- Lack of knowledge about the optimal management of the chronic disease.
- Low level of knowledge about effective antibiotic prophylaxis to prevent endocarditis following an acute episode.
- Which risk factors are associated with transmission to humans in Québec?
- Can we plan interventions to better prevent aerosol transmission in areas surrounding farms (e.g., windbreaks)?
- Do the breeders of small ruminants comply with the preventive measures recommended by the MAPAQ?

Challenges

- Underdiagnosis and underreporting of Q fever cases, because the disease is self-limiting or subclinical in some cases.
- Investigations related to human cases have limited effectiveness (except in the event of a potential outbreak) in identifying sources of exposure and contributing to the description of the epidemiology in Québec: an epidemiological analysis of human and animal data would be necessary.
- Major human outbreaks are associated with aerosol dispersion in the environment.
- The delay in obtaining human test results and thus in reporting to the MAPAQ, makes it difficult to identify a possible source of exposure, which is already a challenge given the aerosol route: animal exposure is often not identified. Lack of knowledge about animal epidemiology on a smaller scale by health professionals and therefore difficult for them to consider this diagnosis when the clinical signs are not very specific or short-lasting.
- Diagnosis in animals is somewhat challenging, but made easier through the submission of aborted fetuses and placentas.
- Clinical suspicion and a detailed medical history are often necessary a priori, given the non-specific clinical signs.
- Challenge of preventing and treating the chronic disease in humans.
- Improving the suspicion index for physicians regarding at risk groups or people susceptible to contracting Q fever (e.g., immunocompromised individuals, farm operators, veterinarians, slaughterhouse workers and people living near agricultural operations). Pregnant women and people with heart valve disease are more prone to develop chronic Q fever.

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Giardiasis

Authors

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Pathogen: protozoan parasite, *Giardia lamblia (*syn. *G. duodenalis, G. intestinalis),* of which only genetic assemblages A and B are zoonotic, including human infection).

Primary animal reservoir in Québec: For the zoonotic assemblages: cattle; wild mammals (possibly beavers, muskrats, other).

Table 7 Burden of giardiasis in public health and animal health

Prioritization criteria	Human	Animal
Symptoms or clinical signs/Severity/Morbidity	Nausea, epigastric pain, anorexia, fever, soft foul-smelling stools. Possible complication: malabsorption syndrome with vitamin and lactase deficiency, post-infection irritable bowel syndrome (chronic forms).	Generally asymptomatic. Moderate to severe diarrhea; chronicity (malabsorption).
Duration	Symptom onset: 6 to 16 days after contamination. Duration of symptoms: up to one month.	Varies by etiological agent and affected animal.
Lethality	Rare.	Occasional.
Groups at risk of acquiring the infection and complications	Immunocompromised individuals, travel/stays in endemic countries, people engaging in outdoor and swimming activities, consumers of unfiltered or untreated surface water, children in daycare facilities, anyone in close contact with livestock and domestic animals (e.g., according to occupational activities: farmers, veterinarians, technicians).	Assemblages A or B: domestic livestock (cattle, swine, sheep, horses), wildlife (beavers, muskrats), pets (cats, dogs). Young animals particularly at risk of being shedders.
Incidence over the past 5 years (Québec)	Rate/100,000 and 95% CI (BSV, MSSS, 2016): 2015: 12.25 (11.52-13.03) 2014: 11.13 (10.43-11.87) 2013: 11.87 (11.14-12.64) 2012: 12.01 (11.28-12.79) 2011: 12.08 (11.34-1.86) Average rate 2011–2014: 11.77 (11.40-12.15) Average rate 1990-1995: 10.4/100,000. The increase in the incidence rate in industrialized countries may be due to more frequent detection and better diagnostic methods[2].	Prevalence: 45.7% of dairy farms in Québec positive[3].
Trend	Epidemic peaks in late summer, early fall.	No documented or observed trend.
Economic burden	Not measured in Québec.	Reduced productivity, low weight.
Social impacts	Greater in developing countries (malnutrition, growth delay, cognitive deficit).	Not significant.

Transmission potential (A-H; H-H; A-A; H-A)

- A-H: via consumption of contaminated food and water (especially drinking water, particularly unfiltered surface water sources; also via recreational water). Few documented cases of transmission by dogs or cats.
- H-H: fecal-oral (especially in children) and indirectly via drinking water and recreational water if contaminated by wastewater).
- H-A: fecal-oral transmission.
- A-A: fecal-oral transmission.

Link(s) to climate change: environmental factors with a documented or potential impact on the dynamics of this zoonosis

- Temperature: positive association with the rise in temperature observed in New Zealand and the United States [4].
- Precipitation: positive association between the increase in the frequency, intensity and duration of precipitation (extreme climate events leading to overflowing sewer systems and flooding) and the number of cases reported[5].
- Change in agricultural land use (density of cattle by region and farm, ratio of farms to humans; proportion of land where manure is applied); agricultural land use patterns can influence pathogen load by altering the distribution of infectious and vulnerable hosts and can modify transmission routes[6].

Surveillance or early detection measures in Québec

- Surveillance for human cases: cases reported to the regional public health authorities by physicians and laboratories and entered into the MADO registry.

Prevention and control measures in Québec

- Regulation Respecting the Quality of Drinking Water (section 5.1)[7]: water filtration plants use criteria based on the log removal of parasites (*Giardia* and *Cryptosporidium*). Treatment intensity is based on the concentration of the indicators used (*E. coli*, total coliforms) to evaluate the microbiological quality of their water (source water and drinking water). In Québec, unlike other jurisdictions, especially the United States and some Canadian provinces, plants do not test for the presence of *Giardia* cysts.
- *Guidelines for Canadian Drinking Water Quality*: when the presence of cysts or oocysts infectious to humans is suspected or established (during environmental surveillance), or if *Giardia* or *Cryptosporidium* are found to be responsible for infectious water-borne outbreaks in a community, a special program for the treatment and distribution of drinking water must be implemented, along with a watershed and wellhead protection plan (where feasible) or other measures designed to reduce the risk of disease.
- Regulatory measures (AOR and WWPR), and certifications (biological, CanadaGAP) governing manure and slurry management, along with the support provided by agricultural advisory services (services *Agri-conseils)* and the *Prime-Vert* program.

- Preventive practices recommended by the MAPAQ and the MSSS regarding hand hygiene after handling animals or working in a barn or in a child daycare facility. Wash garden vegetables before eating them. Avoid ingesting untreated water (lakes, streams, rivers). Public swimming pools: shower before entering the pool; exclude people with diarrhea, and forbid food consumption on site.
- Recommended preventive measures associated with environmental hygiene for animals.
- Control: drinking water filtration and disinfection; boil water for at least one minute; find alternative water source or use bottled water.
- Antiparasitic therapy with metronidazole for infected persons, where indicated.

Other potential surveillance, prevention and control measures

- A protozoan pre-screening step in water distribution systems helps identify the water sources that are particularly vulnerable to contamination by this type of pathogen[8].
- Take into account the nature of the problem potentially responsible for the presence of oocysts: quality of raw water (proximity to agricultural land), performance of water treatment equipment and components, and some particular climate events (e.g., floods).
- In case of an outbreak: increase public health messages about prevention related to hand washing and good practices to prevent fecal-oral contamination.
- Ultraviolet treatment may be used in the absence of filtration.

Knowledge gaps

- Advance our understanding of transmission in the population by developing a portrait of genetic diversity (molecular epidemiological studies) and by identifying the reservoir.
- What impact will the Québec Policy on Residual Materials have on the risk associated with environmental or food-borne exposure?

Challenges

- Risk analysis is not easy given the difficulty with detecting cysts in drinking water and the lack of an adequate risk assessment indicator (lack of correlation between total coliform and *E. coli* tests performed to test water quality and to test for the presence or absence of *Giardia*).
- Environmental factors documented as having an impact on the dynamics of giardiasis should be taken into account when planning public health responses to ecological risks and when developing policies involving climate change.
- Variability in municipalities' drinking water filtration performance levels could be an issue in a context of climate change: municipalities using surface water are legally obligated to use filtration, but Québec still has some small water systems (fewer than 200 people) without filtration and whose fecal contamination indicators are fecal coliforms or *E. coli.*
- Difficulty with enforcing preventive measures in public pools and public resistance to applying these measures (e.g., showering before entering a swimming pool, excluding people with diarrhea).
- The parasite is resistant to the chlorine concentrations used in swimming pools (contact time required to deactivate the parasite: 45 minutes at 1 mg/L)[1].
- Challenge in terms of good agricultural practices linked to soil fertilization with potentially contaminated manure or slurry (potential for runoff into waterways).
- Given that outbreaks are not always investigated in depth (except in daycare facilities), it would be important to further our knowledge about the sources of water contamination and to document them in order to obtain a portrait of potential contamination sources, either zoonotic or other.
- Cyst detection is a long process, which requires experienced staff.

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Avian and swine influenza

Authors

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Pathogen: influenza A virus (RNA virus belonging to the family of *Orthomyxoviridae*, classified by subtype based on hemagglutinin (HA) and neuromidase (NA); there are 16 H subtypes and 9 N subtypes).

Avian influenza: subtypes including all known HA and NA.

Swine influenza: subtypes mostly present in Québec: H3N2, H1N1 and H1N2. Swine are capable of being infected by human and avian influenza and may play an important role in viral reassortment.

Human influenza: subtypes mostly present in Québec: H1N1 and H3N2, responsible for seasonal flu. Avian and swine flu sporadically cause infections in humans, rarely followed by inter-human transmission. However, the evolution of a strain of animal origin may lead to sustained inter-human transmission and cause a pandemic, as in the case of the H1N1 pandemic in 2009.

Primary animal reservoir in Québec avian (wild birds).

Table 8 Burden of avian and swine influenza in public health and animal health

Priorization criteria	Human	Animal
Symptoms or clinical signs/Severity/Morbidity	**Human seasonal flu**: varies by strain and affected population (1%–2% of the people who contract human seasonal flu must be hospitalized). **Human swine flu (H1N1, H1N2 and H3N2),** nothing indicates that these subtypes are more severe than human seasonal flu. **Human influenza of avian origin (H5N1 or H7N9):** the hospitalization rate of documented cases is 99%[1]. Other avian subtypes (H5N2, H5N6, H7N7, H7N2, H7N3, H9N2, H10N7, H10N8) lead to benign manifestations (e.g. : conjunctivitis).	Variable: asymptomatic to fatal, depending on the animal, the subtype and the strain. Low pathogenic avian influenza (LPAI): In poultry, limited clinical signs. In wild birds, usually asymptomatic. Highly pathogenic avian influenza (HPAI): In wild birds, not well documented and variable. In poultry, systemic and fatal infection: apathy, problems with egg production, edema of the head, respiratory signs, neurological signs, diarrhea. **Swine**: Variable: asymptomatic until acute illness (fever, lethargy, respiratory signs, more rarely, abortions).

Table 8 Burden of avian and swine influenza in public health and animal health (cont'd)

Priorization criteria	Human	Animal
Duration	Duration of symptoms associated with a case of human seasonal flu: 7 to 10 days. There is no suspected chronicity with current human viruses.	**Swine**: incubation period from 1 to 3 days, rapid recovery (4–7 days after onset of symptoms, if there is no concomitant infection or complication). Shedding in the 24 hours following infection, generally persists for 7 to 10 days. **Poultry**: incubation period from a few hours to a few days.
Lethality	**Human seasonal flu**: less than 1%, (or 4%–6% of hospitalized cases) depending on the strain, the season and the population's immunity to circulating strains, and vaccine effectiveness**.** For **human swine flu** associated with the subtypes H1N1, H1N2 and H3N2, nothing indicates that it is more lethal than human seasonal flu. **Human influenza of avian origin**: H5N1 or H7N9; 60% and 40 % of cases, respectively.	Varies by animal, subtype and strain **Swine**, low mortality (around 2%) but high morbidity (up to 100%)[3,7]. **Poultry**: very high mortality (90% to 100%), with a highly pathogenic strain often within 48 hours[9].
Groups at risk of acquiring the infection and complications	**Human seasonal influenza**: persons aged 60 years and older, children younger than 2 years, people with cardiac or pulmonary disease, diabetes, metabolic disorders, obesity, liver, kidney or blood disorders, cancer, immune deficiency or immunosuppression. The risk of **zoonotic transmission** may be higher among workers in the swine or poultry industry[10].	Swine
Incidence over the past 5 years (Québec)	It is estimated that each year around 5% of the population contracts **seasonal flu.** In Canada, the incidence of **human influenza of avian origin** is not well documented. Since 2003, only 3 cases have been reported in Canada (H5N1 in Alberta in one patient from China, and 2 cases of H7N9 in British Columbia) and none in Québec. In the United States, more than 300 cases of the **H3N2 subtype** were identified in 2012.	**Swine influenza** endemic in herds in North America (mostly classical H1N1, H3N2 and pandemic H1N1). No case of **HPAI** in Québec. In Ontario, 3 cases in 2015. In British Columbia, 1 case in 2015 and 12 cases in 2014; 1 case in Manitoba in 2010. In the United States, in 2014 and 2015, 232 commercial and backyard flocks were infected. A new case was reported in Indiana in 2016.

Table 8 Burden of avian and swine influenza in public health and animal health (cont'd)

Priorization criteria	Human	Animal
Trend	Stable, **seasonal flu** seasons vary in length and intensity, depending on the strain, the season and the population's immunity to the circulating strains. However, no clear trend has emerged.	Over the last decade, there has been a significant increase in the diversity of **influenza A in swine** around the world11]. **Influenza of avian origin**: the emergence of new strains (H7N9 and H5N6 subtypes), which may circulate seasonally in birds, has been observed. The Asian lineage avian influenza A (H7N9) is of particular concern because it causes asymptomatic infections in birds, while it causes severe infections in humans.
Economic burden	Undetermined, few studies have evaluated the economic burden of seasonal flu. A study conducted in the United States evaluated that the annual economic burden of seasonal flu amounted to $87.1 billion, including a direct medical cost of $10.4 billion[12].	Variable; High in the case of avian H5 and H7 influenza viruses. In **swine**, economic losses are substantial enough for producers to vaccinate their animals.
Social impacts	Variable if a seasonal or pandemic strain. Seasonal strains are generally socially accepted, pandemic strains of animal origin or those with increased morbidity or mortality are less so.	Difficult within the industry for avian H5 and H7 influenza. Moderate for the swine H1N1 pandemic within the swine industry.

Transmission potential (A-H; H-H; A-A; H-A)

- A-H: For influenza of avian origin, the risk is locally low; abroad, it varies by country visited and travel habits. Increased mobility and travel in at-risk areas could also lead to an increased risk. Wild birds are the natural reservoir of influenza A, and all influenza A strains (human or animal) are likely derived from avian influenza[13].
- H-H: When influenza adapts to humans, it is transmitted relatively easily, when an infected person coughs or sneezes near others. It is the cause of annual epidemics ranging in magnitude and may lead to pandemics. In general, avian or swine influenza results from prolonged or very close contact with a sick animal, but the potential for inter-human transmission is virtually nil.
- A-H: It is believed that avian influenza is not easily transmitted to humans and that, when it does so, it may rarely sustain human-to-human transmission. Swine influenza causes sporadic infections in humans, but rarely subsequent inter-human transmission. Several cases have been identified in the United States[4].
- H-A : The risks of human-to-animal transmission of seasonal flu are not well known. The 2009 H1N1 flu pandemic strain has widely circulated among humans and among swine in recent years. While possibly being quite frequent in swine; according to phylogenetic analyses, a large majority of the exchanges resulting in sustained transmission of the virus in the new population occurred from humans to swine [2,14]. Humans are likely a major source of viral diversity in swine [2]. The classical H1N1 strain, which is endemic in swine in North America, is derived from the human H1N1 strain in 1918, which was responsible for the Spanish flu [5].

Link(s) to climate change: environmental factors with a documented or potential impact on the dynamics of this zoonosis

- Temperature: effect of average winter temperature on human seasonal flu. If the preceding winter were mild, fewer people would have been infected and the population could be more susceptible to contracting influenza in the following season[15]. Rising temperatures could increase the presence of migratory birds in the subarctic region, which increases the risk of inter-species transmission (bird-to-bird and bird-to-human)[16]. No large-scale impact yet; will follow climate evolution.
- Temperature and precipitation changes should have an impact on the migration patterns of several wild birds, the natural reservoir of the virus[17]. No large-scale impact yet; will follow climate evolution.

Surveillance or early detection measures in Québec

- Surveillance for human cases: via Québec's influenza surveillance system, coordinated by the Bureau de surveillance et de vigie of the Ministère de la Santé et des Services sociaux.

Prevention and control measures in place in Québec

- Vaccination targeting particular population groups; the most effective measure, but with variable effectiveness. Currently, there is no vaccine against the emerging strains or those of animal origin; Established system; feasibility depends on vaccine production times.
- Respiratory hygiene/cough etiquette; less documented effectiveness, but generally less effective than vaccination; easy to perform, but variable compliance.
- Surveillance for circulating strains (WHO program); the LSPQ participates with the National Microbiology Laboratory (NML) in the surveillance program on circulating influenza strains by typing isolates. Given that a minimal fraction of the isolates that have caused influenza in humans has been typed, the likelihood of detecting a zoonotic transmission event is very low.
- Active surveillance for avian influenza by the CFIA and enhanced passive surveillance by the MAPAQ for swine, poultry and wild birds. H5 and H7 avian influenza are diseases reportable to the CFIA and to the World Organization for Animal Health (OIE); beneficial, recognized effectiveness within commercial trade for the avian industry; passive surveillance already in place in pig farming (free testing program) and for poultry (systematic analyses during necropsies for birds of over 21 days); passive surveillance for dead or dying wild birds reported by the public.
- Vaccination of swine; variable effectiveness; often applied.
- Biosecurity for swine farming. Hygiene and individual protection for workers. Regulation on bird quarantine to prevent all direct or indirect contact between domestic birds and wild birds.

Other potential surveillance, prevention and control measures

- Farm biosecurity
- Worker hygiene and personal protective equipment; some measures may be less acceptable to workers (e.g. wearing a mask).
- Swine vaccination; not always effective, depending on the speed of strain mutation; often applied, especially to control episodes.

- Vaccination of the public; could effectively decrease the economic burden of annual influenza by reducing infections due to the virus and viral shedding [12, 18]. Vaccine development and production using current technology requires a minimum of six months.
- Antivirals: costly given that few molecules have proven efficacy. The zoonotic strain must be sensitive to antivirals.
- Vaccination for swine industry workers against human seasonal influenza. Few available data. Limiting co-infection risks would reduce the possibilities of reassortment between swine and human viruses.
- Depending on acceptability by workers and the efforts invested to ensure good vaccination uptake. Currently possible for workers to get vaccinated on a voluntary basis, but not free of charge.
- Surveillance: several programs already in place.

Knowledge gaps

- Risks of zoonotic influenza transmission from unknown animals. Animal-human transmission potential still not very well documented. Need for further research to better understand the epidemiology at the animal-human interface. Risk of reassortment in humans infected by viruses of animal and human origin: exchanges of segments originating from different species in a co-infected individual. The probability of a human infection with the influenza virus is the direct result of a dynamic interaction between animal health, environmental factors and the human host's immune system[4].The mechanisms or characteristics of strains sustaining inter-species transmission are still not fully understood[5].
- Human-animal transmission potential not very well documented. Need for further research to better understand the epidemiology at the animal-human interface. The risk of reassortment in swine, which are very susceptible to being infected by viruses of various origins (avian, human, swine): exchange of segments coming from different species in a co-infected individual.
- Lack of knowledge about the ecology of the influenza virus. All possible hosts are still not known, and little information is available on inter-species transmission[4].
- Lack of knowledge about sequencing to gain a better understanding of the evolution of the virus.
- Environmental factors that facilitate virus transmission: temperature and relative humidity have been suggested but are not vey well documented.
- Are measures, such as excluding sick workers or having swine industry workers wear masks, effective for reducing the risk of herd infection?
- Lack of knowledge about virus transmission between workers and animals.
- Surveillance of wild birds should be reviewed to target the birds at most risk of being infected by the strains of concern (e.g., Asian strains in birds transiting through Arctic regions before flying south) and to target the environments that are particularly at risk of infecting adjoining farms. Could the research to detect the influenza virus in wetland sediments, as being tested in British Columbia, effectively contribute to surveillance?

Challenges

- The documented cases of human influenza of avian origin are likely the most seriously affected. This may then lead us to suppose that the severity has been overestimated[1]. Increased surveillance for highly pathogenic avian influenza A (in animals) is demonstrated, but the relationship between pathogenicity for humans and each subtype of zoonotic origin must be documented.
- Cases of human influenza of avian origin are mostly reported in countries with a high incidence of outbreaks in animals. Contact with infected poultry, whether sick or dead, seems to be a risk factor for H5N1, but this relationship seems less clear for H7N9 influenza or for emerging subtypes such as H5N6.
- Incidence is difficult to determine both for human influenza and for influenza of animal origin; which depends on the country, the thoroughness of its surveillance practices and its diligence in reporting cases to the World Health Organization (WHO).
- Climate change could have a difficult-to-predict impact on the migration of wild birds and could thus modify the risks of inter-species transmission.
- A risk of a pandemic exists following the mutation of animal strains, which could allow sustained inter-human transmission. In such a scenario, humans do not yet have immunity, and a large proportion of the population could become ill [3].
- The worst pandemic known in history is the 1918 Spanish flu, which killed 40 million people, and which may have been caused by a virus of avian origin that may have acquired the potential for inter-human transmission.
- Equine influenza is one of the diseases of importance to international trade, according to the OIE, and is highly contagious between horses. There are two subtypes likely derived from avian influenza, that is, H7N7 influenza A (type 1, not very present over the past 30 years) and H3N8 (type 2), also affecting donkeys and mules. The H3N8 subtype can also infect dogs, and in 2004 and 2006, in China, two equine H3N9 viruses were isolated in swine. The equine influenza virus may not cause illness in humans, but there is serological evidence of infection with H3N8 in humans with occupational exposure to the virus[6]. In recent years, there have been regularly suspected cases of equine influenza (rarely laboratory confirmed), especially in Québec, Ontario and British Columbia. Circulation of the H3N8 subtype has been documented in Québec.
- Canine influenza: H3N8 and H3N2 subtypes. The canine H3N8 influenza virus may have evolved from the equine H3N8 influenza virus (but may no longer have the ability to infect horses) and has been present in the United States since 2004. The canine H3N2 influenza virus appeared in Asia and may have evolved from an avian strain. it has been present in the United States since April 2015 and may have the ability to also infect cats[8]. No human infection caused by the canine influenza virus has been reported, and its presence has not been confirmed in Canada.
- Several other species are hosts to the influenza virus, including whales, seals, bats and ferrets. The ecology of the virus is very complex, given its great ability to adapt, and our knowledge about this topic is still limited.
- Many uncertainties make it difficult to estimate the economic burden in the event of a pandemic, but the economic burden would potentially be very high.
- With temperature fluctuations due to climate change, influenza seasons are likely to become less predictable. The highly pathogenic H5N1 virus can survive in bird droppings for at least 35 days at 4° C, and at higher temperatures (37° C), the H5N1 virus could survive for 6 days.

- Changing migration patterns should influence the epidemiology of avian influenza, particularly with regard to cross-species transfers, leaving us uncertain about the evolution of this disease and about new reassortment possibilities. Need for enhanced surveillance.
- Given its proximity to Arctic zones, Québec is an area where the probability of contact with avian wildlife is likely to increase, thereby increasing the risks of avian influenza transmission.
- Farm biosecurity: very important, but not enough to protect a herd against influenza.
- Speed of viral mutation.
- Seasonal flu vaccines are reformulated every year according to the strains circulating in the two hemispheres. Effectiveness varies according to the strain (better for the H1 viruses and less so for the H3 viruses), the type of vaccine, the match between the circulating strain and the strain contained in the vaccine, and the affected populations.
- The introduction of human seasonal viruses into swine populations plays a central role in the evolution and diversity of swine viruses[2].
- Could vaccinating swine industry workers be an effective measure for reducing a herd's risk of infection?
- The development of an integrated surveillance system (including at least avian, swine and human influenza) using genomic tools must enable the early detection of emerging strains and the documentation of the epidemiology of the virus at the human-animal interface.
- The lack of genomic tools to optimize surveillance does not make it possible to ensure good vaccine effectiveness.
- Difficulty with targeting influenza cases at risk of representing a zoonotic transmission event and with including them in strain surveillance.
- Flooded farmlands could be particularly at risk.

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Lyme disease

Authors

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Pathogen: *Borrelia burgdorferi* sensu stricto (s.s.)

Primary animal reservoir in Québec: Micromammals (i.e., primary reservoir – white-footed mouse *Peromyscus leucopus*), migratory birds

Primary vector in Québec: Tick, *Ixodes scapularis (I. scapularis)*

Table 9 Burden of Lyme disease in public health and animal health

Priorization criteria	Human	Animal
Symptoms or clinical signs/Severity/Morbidity	Not very severe in the acute stage, more severe if diagnosis is made in the late disseminated stage. **Early localized stage**: skin reaction in 70%–80% of infected persons, accompanied or not by general symptoms (fever, fatigue, headache, neck stiffness, muscle and joint aches) within 3 to 30 days post tick bite. **Early disseminated stage**: cardiac manifestation, neurological (weeks, several months). **Late disseminated stage**: joint and neurological manifestations (several months, years if untreated). Permanent sequelae are possible through tissue damage associated with the long evolution of the untreated disease.	Dogs: 5% symptomatic, not very to moderately severe (arthritis), save exceptions (e.g., neuropathy). Horses, donkeys, and mules: fatigue, fever, loss of appetite, behaviour change, stiffness and swelling in some joints[6]. No scientific evidence for the disease in cattle and cats.
Duration	Days-weeks (early localized stage) to months-years (disseminated stages).	Days (acute) to months (disseminated).
Lethality	Low, 5 cardiac deaths (myocarditis) reported in the U.S. in recent years[7].	Low, except for cases with renal complications.
Incidence over the past 5 years (Québec)	Rate/100,000 and 95% CI (BSV, MSSS, 2016) 2015: 1.87 (1.60-2.19) 2014: 1.52 (1.28-1.81) 2013: 1.75 (1.49-2.07) 2012: 0.53 (0.39-0.72) 2011: 0.40 (0.28-0.57) Average rate 2011–2014: 1.06 (0.95-1.17)	Seroprevalence in dogs in Canadian provinces: 0–2.15% (Québec: 0.57%)[3, 8].

Table 9 Burden of Lyme disease in public health and animal health (cont'd)

Priorization criteria	Human	Animal
Groups at risk of acquiring the infection and complications	▪ People who engage in outdoor leisure or work activities near woodlands in an endemic area. ▪ People whose primary or secondary residence is located in woodlands or in proximity to an endemic area. ▪ Most affected age groups in Québec and the U.S. : 5–15 years and 55 years and older[9, 10].	Dog breeds at risk for renal complications: Labrador and golden retriever[11].
Trend	Endemic areas recognized in southwestern Québec[3, 12, 13]. Expectation: increase in the incidence of human cases in the affected areas, and geographic expansion of the tick vector, causing more affected regions. Increase in peridomestic epizootic outbreaks for the groups of people whose primary or secondary residence is located in proximity to woodlands in endemic areas.	Endemic areas recognized in southwestern Québec[3,12,13].
Economic burden	Economic impact not measured: ▪ Costs linked to case management (investigations, treatments, medical visits, travel, work absenteeism), especially if diagnosis is not made in the early stage and at the prevention stage; ▪ Costs linked to untreated disseminated disease and to persisting symptoms after Lyme disease treatment. ▪ Cost of the prevention strategy at all levels of government: ▪ Surveillance to identify risk areas; ▪ Awareness campaign for the general public and health professionals. ▪ Other costs to be expected in relation to climate change[14].	Low, owners of domestic animals (mostly dogs): veterinary costs (prevention and/or treatment).
Social impacts	▪ High anxiety and lack of confidence felt by certain groups with respect to the diagnosis of the disease, treatment effectiveness (e.g., late disseminated disease, post-treatment syndrome) and tick-control measures; ▪ Prevention strategy for landscape management of parks, campgrounds, hiking trails, etc.; ▪ Enactment in 2014 of federal legislation, Bill C-442, Federal Framework on Lyme Disease Act.	Moderate to high anxiety for owners of dogs and horses.

Transmission potential (A-H; H-H; A-A; H-A)

- A-H: Vector transmission to a human via an *I. scapularis* tick (i.e., nymph and adult) infected by an animal host reservoir.
- H-H: Theoretical risk (no identified case) at the time of blood or organ donations[15].
- No scientific evidence on sexual transmission, intra-uterine transmission and via breast milk.
- A-A : Vector transmission to an animal via an *I. scapularis* tick (i.e., nymph and adult) infected by an animal host reservoir.
- H-A: N/A.

Link(s) to climate change: environmental factors with a documented or potential impact on the dynamics of this zoonosis

- Documented link to meteorological and climate conditions: temperature index, humidity, precipitation, drought, latitude, altitude, winter season, etc.[16-18].
- High potential for introduction, emergence or expansion in new regions of Québec[3,4,19]
- Change in the length of the tick season (e.g., milder winters).

Surveillance or early detection measures in Québec

- Surveillance for human cases: cases reported by physicians and laboratories and entered into the MADO registry: real-time reporting for laboratory-confirmed cases.
- A passive surveillance system for ticks of human and animal origin is in place.
- An (active) field surveillance system for ticks in the environment or on wild animals (reference method) makes it possible to confirm and identify endemic areas.

Prevention and control measures in Québec

- Communication strategy at the federal, provincial and regional levels (risk areas).
- Continuing education for health professionals.
- Communication to the general public regarding risks.
- No vaccination for humans; vaccination available for dogs.
- No tick vector control measure to date.
- Public education/awareness provided by public health authorities and professional associations.

Other potential surveillance, prevention and control measures

- Prevention strategies: posters in parks located in endemic areas (targeting most popular sites at greatest risk) or use of electronic media to raise awareness in a target audience[20].
- Surveillance of exposure to disease risk via dogs (seroprevalence or clinical animal cases).
- Control strategy in the United States: measures via the use of acaricides targeting peridomestic rodents, vaccination of rodents (reservoir hosts of Lyme disease).

Knowledge gaps

- Lack of knowledge regarding endemic areas. Integrated surveillance has limitations, resulting in the unknown endemicity of many areas. Development of a standardized provincial surveillance strategy. Underestimation and underreporting of the number of human and animal cases[1,2]?

Challenges

- Anxiety and lack of confidence expressed by certain groups of the population.
- Increase in Lyme disease cases in Québec and Canada (humans and dogs).
- Wide spatio-temporal variability in the risk of exposure to Lyme disease (i.e., density of infected ticks very locally variable, wide variability in the prevalence *I. scapularis* tick infection in the endemic areas, according to the data of active surveillance programs in Canada[3-5].
- Difficulty with making a diagnosis, according to the stage of the disease.
- Treatment is effective in most cases, but there are problems and challenges associated with the treatment of patients with persistent symptoms.
- Lack of an integrated surveillance program for diseases transmitted by ticks (e.g., anaplasmosis) or more generally for vector diseases (e.g., California serogroup arbovirus).

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Rabies

Authors

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Pathogen: Rabies virus (rhabdovirus): bat variant, Arctic fox variant, raccoon variant.

Primary animal reservoir in Québec: Arctic foxes, raccoons, and bats.

Table 10 Morbidity, lethality, duration and groups at risk for rabies (all variants)

Priorization criteria	Human	Animal
Symptoms or clinical signs/Severity/Morbidity	Symptoms and signs related to severe meningo-encephalitis. The main clinical manifestations include agitation, sleepiness, confusion, muscle paralysis or spasms, cardiac arrhythmias, progressing to coma before death. Hydrophobia is a presentation quite specific to humans.	Symptoms and signs related to severe meningo-encephalitis. The main clinical manifestations are behaviour changes, hypersalivation and other neurological signs.
Duration	▪ Incubation period: generally ranges from 20 to 90 days but may extend from 2 weeks to several months, rarely a few years. The incubation period varies according to the quantity of inoculum, the site of inoculation, and its level of innervation; ▪ Without intensive supportive care, death generally occurs within 14 days of disease onset[1]; ▪ There is no difference in the clinical presentation of human rabies, by variant.	Generally in terrestrial mammals: ▪ Incubation period: 2 weeks to several months (depending on the infection site and species); ▪ Duration of clinical signs varies by species and variant; ▪ The period of preclinical shedding of the virus in saliva varies by species. It is less than ten days in dogs, cats and ferrets.
Lethality	Considered to be 100% fatal (existence of rare confirmed cases and suspected cases of rabies that survived, often with significant neurological sequelae).	Considered to be 100% fatal.
Incidence	See specific fact sheets.	See specific fact sheets.

Table 10 Morbidity, lethality, duration and groups at risk for rabies (all variants) (cont'd)

Priorization criteria	Human	Animal
Groups at risk of acquiring the infection and complications	The following groups are at increased risk of exposure to the rabies virus, owing to their close and frequent occupational contact with animals, or at risk of occult contact[2]: ▪ laboratory workers handling live rabies virus; ▪ veterinarians and their assistants in state animal pathology laboratories and those working in rabies-enzootic areas; ▪ veterinary medicine students and staff employed at the Faculty of Veterinary Medicine at risk of exposure to the rabies virus; ▪ persons handling potentially rabid bats or performing activities involving a high risk of exposure to potentially rabid bats; ▪ animal control officers[3]; ▪ wildlife control officers[3]. Others who may also be considered to be at greater risk of rabies exposure include individuals who engage in activities, such as hunting, trapping, and cave exploration, which places them in close contact with potentially rabid animals, such as bats, foxes, skunks and raccoons, in areas where rabies is found[3]. There are no conditions that increase the risk of disease complications, once the disease appears.	All mammals are susceptible to being infected and rabid (all variants). Groups at risk of exposure: ▪ Domestic animals such as dogs and cats, along with livestock, are susceptible to exposure; ▪ Wild animals are more exposed but are less detected.

Table 10 Morbidity, lethality, duration and groups at risk for rabies (all variants) (cont'd)

Prioritization criteria	Human	Animal
Potential for causing outbreaks / Disease trend	Although inter-human transmission is uncommon (no human epidemic in the strict sense), an epidemic of animal rabies can lead to an increase in human cases, It is due only to post-exposure prophylaxis (PEP) that outbreaks of human cases do not occur in Québec. Such outbreaks occur elsewhere in the world (canine rabies especially because of limited access to effective PEP).	See specific fact sheets.
Economic burden	Moderate, owing to PEP: ▪ Costs of biological PEP products ($1464/PEP); ▪ Costs in human resources for risk assessment and PEP administration; ▪ Animal testing ($269/test); ▪ Investigations ($124/investigation). Globally, preventive and post-exposure measures, reporting exposures, management and required care.	Low to moderate for owners of domestic animals, who must pay for pre-exposure and/or post-exposure vaccination (if contact) for their animals.
Social impacts	See specific fact sheets.	See specific fact sheets.

Transmission potential (A-H; H-H; A-A; H-A) (all variants)

- A-H: High potential for transmission to humans in contact with reservoir species or suspect animals.
- H-H: Rare, organ or tissue donation; exposure to the saliva of a sick person; exposed people must receive PEP (healthcare context and interpersonal relations).
- A-A : High potential for transmission to an animal in contact with reservoir species or rabid animals.
- H-A: N/A.

Link(s) to climate change: environmental factors with a documented or potential impact on the dynamics of this zoonosis

The distribution of the different rabies variants will be subject to more or less significant changes linked to climate change (species adaptation).

Surveillance or early detection measures in Québec (all variants)

- Surveillance among humans:
  - Rabies is a reportable disease for confirmed human cases, which are reported to regional public health authorities by physicians and laboratories and entered into the MADO registry.

- Surveillance among animals:
  - Rabies is a reportable disease at the federal level (CFIA) for confirmed cases in wild animals.
  - Rabies is a reportable disease in Québec (MAPAQ) and at the federal level (CFIA) for confirmed domestic animal cases. In addition, suspect domestic animal cases are reported to the MAPAQ by veterinarians.

- Passive surveillance coordinated by the MSSS, the MFFP and the MAPAQ (risk of rabies exposure):
  - Veterinary investigation (MAPAQ) when a domestic animal is involved in an incident exposing a human to the risk of rabies. An investigation is also conducted in cases of sick domestic animals presenting with suspect clinical signs.
  - Veterinary investigation (MFFP) when a wild animal is involved in an incident exposing a human to the risk of rabies.
  - Depending on the investigation, wild or domestic animals involved in an incident exposing a human to the risk of rabies may be tested at the CFIA laboratory.
  - An observation period may be initiated if euthanizing the animal is not desirable, according to the species in question, all occurring as part of the investigation. For example, for dogs, cats and ferrets, priority is given to observation before testing.

- Continuous surveillance of wildlife diseases: the MFFP collects certain suspect or dead wild animals across Québec (without the risk of rabies exposure) for necropsy at the Centre québécois sur la santé des animaux sauvages (CQSAS). Positive or suspect rabies results are confirmed by the CFIA laboratory.

Prevention and control measures in Québec (all variants)

Animal health:

- Vaccination of domestic animals (recommended).
- Municipal by-laws concerning, for example, administering the anti-rabies vaccine to dogs and sometimes cats and stray animals.

Human health:

- Pre-exposure vaccination is possible for people working with wild and domestic animals.
- Individual evaluation of every person having had significant exposure, and recommendations for PEP, according to an established protocol (PIQ algorithm Chapter 10.7 and rabies intervention guide[1]), involving multiple interventions by several primary care workers in the healthcare system.
- Communication to increase vigilance among veterinarians, other stakeholders and the public (MAPAQ, MSSS, MFFP).

Other potential surveillance, prevention and control measures (all variants)

- Education program targeted toward at-risk groups (e.g., children).
- Animal population control program – sterilization.
- Free or low-cost animal vaccination program.
- Oral vaccine bait drops for stray dogs.
- Legislation respecting the vaccination of domestic animals.
- Legislation respecting bite prevention, and the monitoring of biting domestic animals.
- Legislation respecting the transport of dogs coming from endemic areas.
- Legislation respecting dog sterilization.

Knowledge gaps (all variants)

- Lack of precise knowledge about actual human and animal PEP treatments and about the impact on people who were exposed and received PEP.
- Epidemiological, anthropological and climatological factors influencing the spread of rabies.

Challenges (all variants)

- No cure for the disease (either in humans or in animals).
- Post-exposure prophylaxis must be administered as quickly as possible after exposure in humans (PEP must be administered quickly after exposure and becomes ineffective upon the onset of clinical signs). PEP in humans consists of the administration of human rabies immune globulin (HRIG), and 4 doses of anti-rabies vaccine over 14 days) (5 doses for immunocompromised people).
- Post-exposure prophylaxis in domestic animals: booster shot or PEP (i.e., dogs, cats, ferrets), which consists of 3 doses of anti-rabies vaccine.
- No treatment for wild animals.
- Significant economic burden owing to the large number of animal bites despite the low epidemic potential in humans[1].
- A few studies show that animals and a very few humans have detectable rabies antibodies without a history of prior vaccination; which leaves us to suspect an infection with no or minimal symptoms with survival.

RABIES – BAT VARIANT (BT variant)

Table 11 Burden of the bat rabies variant in public health and animal health

Prioritization criteria	Human	Animal
Symptoms or clinical signs/Severity/Morbidity	See general fact sheet.	See general fact sheet.
Duration	See general fact sheet.	▪ Incubation period: highly variable and may be extended by hibernation, generally ranging from 14 to 35 days up to 7 months. Bats may shed the virus from 10 to 21 days before the onset of clinical signs. ▪ Symptom duration: 1 to 20 days.
Lethality	See general fact sheet.	See general fact sheet.
Incidence over the past 5 years (Québec)	Around 75% of the human cases in recent years have been associated with the bat rabies variant in North America. The last human case of rabies due to this variant in Québec dates back to 2000.	2011: 9 bats 2012: 2 bats 2013: 14 bats and 1 skunk 2014: 6 bats and 1 cat 2015: 13 bats Cases that emerged from passive surveillance (contact) and continuous surveillance of wildlife diseases (no contact, submitted to the CQSAS then confirmed by the CFIA).
Groups at risk of acquiring the infection and complications	The rabies virus is present in Québec according to the bat distribution range. ▪ People at risk who must be evaluated: anyone who has had physical contact with a bat; ▪ Groups at risk of exposure: see general fact sheet.	▪ The rabies virus is present in Québec regions according to the bat distribution range; ▪ Groups at risk of exposure: see general fact sheet.

Table 11 Burden of the bat rabies variant in public health and animal health (cont'd)

Prioritization criteria	Human	Animal
Potential for causing outbreaks / Disease trend	Very low potential for human rabies epidemic, but exposures to bats are not uncommon[4].	▪ Endemicity of the bat rabies variant for all Québec regions where bats are present. Low potential for an outbreak even though particular situations have been reported, such as several confirmed rabid bats in the same place during a short period of time; ▪ Low potential for an outbreak among domestic animals and wild animals.
Economic burden	See general fact sheet. PEP is recommended for all significant exposures to bats whose rabid status is positive or unknown. Only a negative rabies result avoids the administration of PEP.	See general fact sheet. Low for wild animals: there is no bat rabies control method.
Social impacts	The perception of risk may increase locally in particular situations where several bats are reported to be rabid. Public health authorities and the healthcare system take charge of the necessary care and communications, given the heightened perception of risk.	Heightened perception and anxiety about the risk among domestic-animal owners, who may have been in contact with a bat or in proximity to certain rabies cases.

Transmission potential (A-H; H-H; A-A; H-A)

See general fact sheet.

Link(s) to climate change: environmental factors with a documented or potential impact on the dynamics of this zoonosis

Climate conditions favourable to bats could lead to the expansion of their distribution range (epidemic potential would still remain low).

Surveillance or early detection measures in Québec

Surveillance for white-nose syndrome: the MFFP collects certain dying or dead bats (without at-risk contact) for necropsy at the CQSAS. Tests for white-nose syndrome and the direct rapid immunohistochemical test (dRIT) for rabies are performed by the CQSAS; for positive dRIT tests, results are confirmed by the CFIA with the fluorescent antibody test (FAT).

See general fact sheet.

Prevention and control measures in Québec

- There is currently no bat control method (vaccination).
- Annual public awareness campaigns regarding the safe behaviour to adopt around bats in order to reduce the number of at-risk human contacts (MSSS and MFFP).
- See general fact sheet.

Other potential surveillance, prevention and control measures

- Compulsory training courses, for at-risk groups, on best practices for handling bats.
- See general fact sheet.

Knowledge gaps

- Few studies exist on the bat rabies incubation period and shedding period.
- Little is known about the potential for transmission between land animals infected with the bat rabies variant.
- Few studies on the possibility that certain subtypes of bat rabies variant are more virulent.
- No studies on the impact that the decrease in the populations of certain bat species linked to the white-nose syndrome may have on the dynamics of rabies in the different bat species.
- See general fact sheet.

Challenges

- Effectiveness of annual public awareness strategies on the safe behaviour to adopt with regard to bats.
- Decrease in the number of reports submitted on bats potentially linked to the white-nose syndrome.
- See general fact sheet.

RABIES – ARCTIC FOX VARIANT (AF variant)

Table 12 Burden of the Arctic fox rabies variant in public health and animal health

Prioritization criteria	Human	Animal
Symptoms or clinical signs/Severity/Morbidity	See general fact sheet.	See general fact sheet.
Duration	See general fact sheet.	▪ Incubation period: from 8 days to 6 months; ▪ Symptom duration: 1 to 2 days.
Lethality	See general fact sheet.	See general fact sheet.
Incidence in Québec	The last human case of rabies probably due to the AF variant (exposure to a skunk) dates back to 1964 in Huntington, a town in southwestern Québec.	Between 0 and 16 cases of the AF rabies variant detected annually between 2010 and 2015 among wild and domestic animals in northern Québec (Nord du Québec region). At the time of incursions toward the south of Québec, 20 to 127 cases of rabid red foxes were detected in the 1960s, and 84 to 427 cases in the 1990s (300 cases per year in the Montérégie region from 1989 to 1993). In 2015, 7 cases of AF variant rabies were detected in Labrador City (located near the border of the Nord du Québec region).
Groups at risk of acquiring the infection and complications	▪ Increased risk for northern populations and those in neighbouring areas in case of incursions toward the south: ▪ Individuals (even in the south) who adopt an unvaccinated dog coming from the north; ▪ Risk of unrecognized exposures, particularly among young children[5]; ▪ Groups at risk of exposure: see general fact sheet.	▪ The reservoir is the Arctic fox. The second most affected species is the red fox; ▪ Domestic animals, especially dogs in Northern communities are very susceptible to being exposed; ▪ In case of an incursion toward the south, see general fact sheet.

Table 12 Burden of the Arctic fox rabies variant in public health and animal health (cont'd)

Prioritization criteria	Human	Animal
Potential for causing outbreaks / Disease trend	See general fact sheet.	▪ Endemic in the North among foxes, with apparent epidemic cycles (potential for contact between Arctic foxes, red foxes and dogs); ▪ Low potential for incursion toward the south; however, Québec is not spared from this. From the early 1950s to the end of the 1990s, several epizootic fronts spread to all the regions of southern Québec, via Ontario and eastern Québec and/or Labrador. Starting in the 1990s, aerial distribution of an oral vaccination for foxes in an area in southern Québec helped eliminate the infection in the Outaouais region in Québec.
Economic burden	See general fact sheet. Moderate to high for northern communities[6]. ▪ High rate of PEP per population [5]; ▪ Transportation costs; ▪ Moderate to high for other regions of Québec, in case of an incursion toward the south.	See general fact sheet. ▪ Currently low in endemic area at the provincial level: canine vaccination program, investigations following bites in northern communities; ▪ Potentially high in case of incursion toward the south: the number of preventive and post-exposure vaccinations among domestic animals, and wildlife control operations would increase.
Social impacts	Moderate anxiety in northern communities.	Concern for unvaccinated dogs – risk of bite with possible human or animal transmission.

Transmission potential (A-H; H-H; A-A; H-A)

See general fact sheet.

Link(s) to climate change: environmental factors with a documented or potential impact on the dynamics of this zoonosis

- Very high (anticipated potential) linked to the dynamic changes in the Arctic fox population resulting from melting ice, the disturbance in the lemming populations (primary prey) and the changing distribution and abundance of its competitor, the red fox. The last factor could increase the risk of rabies incursion from the north to the south[7, 8].

Surveillance or early detection measures in Québec

- Wildlife research projects make an ad hoc contribution to surveillance in the Nord du Québec region. However, there is often a delay before results become available.
- See general fact sheet.

Prevention and control measures in Québec

- No large-scale control measure (vaccination) for foxes and wild animals is currently being applied in the northern region.
- Several organizations provide documentation on rabies.
- Each year, the MAPAQ goes to several communities and organizes dog vaccination campaigns. This opportunity is used to address different topics with the people in these communities, such as rabies, controlling stray dogs, vaccination, and so forth.
- Awareness activities for health professionals (provincial and regional) and for the general public (aimed at children).
- See general fact sheet.

Other potential surveillance, prevention and control measures

- Labrador: active/passive surveillance program, regional public health officers.
- Northern Ontario: chemical sterilization program for the canine populations.
- See general fact sheet.

Knowledge gaps

- Spatio-temporal dynamics of rabies, persistence of rabies in the Arctic fox populations, and role of the red fox in the epidemiology of the Arctic fox rabies variant.
- Risks of incursion and establishment in southern Québec.
- Impact of environmental changes (climate changes and anthropogenic changes).
- See general fact sheet.

Challenges

- Lack of knowledge about the epidemiology of the AF rabies variant.
- Risk of incursion to southern Québec.
- Relocation (adoption) of northern dogs to more southern regions, which could create risks of human and animal exposure to the variant in southern Québec.
- Economic and sociocultural context in northern communities, and adaptation and implementation of effective prevention and control measures.
- Difficulty controlling canine populations in northern communities.
- Lack of veterinarians in northern communities.
- Limited reporting of potentially rabid animals (traditionally and because of lack of means, suspect foxes and dogs are killed).
- Control by means of aerial distribution of oral vaccines is not currently considered to be a feasible measure (i.e., vast territory, no effective vaccines in a cold climate, very large distances travelled by foxes).
- Lack of a cost-benefit analysis or study assessing the effectiveness of the intervention strategies.
- Economic development of the North, increasing the number of people living in villages (interactions, new domestic animals, waste management).
- No access to human PEP within the recommended time for certain cases, due to the delay between exposure and medical visit.
- See general fact sheet.

RABIES – RACCOON VARIANT (RR variant)

Table 13 Burden of the raccoon rabies variant in public health and animal health

Prioritization criteria	Human	Animal
Symptoms or clinical signs/Severity/Morbidity	See general fact sheet.	See general fact sheet.
Duration	See general fact sheet.	See general fact sheet.
Lethality	See general fact sheet.	See general fact sheet.
Incidence in Québec	No case of raccoon rabies variant in humans in Canada. Two cases in the U.S. were confirmed rabid with the RR variant in 2011 and 2013[9, 10].	104 cases detected in the Montérégie region between 2006 and 2009 (raccoon: 89, skunk: 14, red fox: 1) and one case in a raccoon in Akwesasne, Québec) in 2015. This last case was associated with an epidemic outbreak that occurred in northern New York State, with 15 cases between March and October 2015.
Groups at risk of acquiring the infection and complications	Increased risk of exposure in the Montérégie and Estrie [Eastern Townships] regions, given the presence of the RR variant in the United States (NY, VT, NH and ME)[11]. ▪ Group at risk of exposure: see general fact sheet.	▪ The reservoir is the raccoon. The second most affected species is the striped skunk; ▪ Groups at risk of exposure: see general fact sheet.
Potential for causing outbreaks/ Disease trend	See general fact sheet.	▪ As a general rule, in regions without effective control measures (U.S.: central and southern part of the East coast), a cyclical endemicity of the RR variant is recognized; ▪ High potential for causing an epidemic among wild animals if no wildlife control measure is implemented (e.g., vaccine bait drops), which would lead to many at-risk contacts with domestic animals and humans. The potential is currently low in southern Québec only because effective control measures have been implemented on a yearly basis in targeted areas, based on the cases identified in the U.S.

Table 13 Burden of the raccoon rabies variant in public health and animal health (cont'd)

Prioritization criteria	Human	Animal
Economic burden	See general fact sheet. Currently moderate because raccoon rabies is absent from Québec, but quickly becomes high in an epidemic situation, based on the cost-benefit analysis performed in 2008[6].	See general fact sheet. ▪ Currently moderate for wild animals because raccoon rabies is absent from Québec: the main cost is associated with surveillance and control operations among wild animals (vaccine bait drops); ▪ High during an epidemic: the number of pre- and post-exposure vaccinations for domestic animals, as well as wildlife control operations, would increase.
Social impacts	High social impacts during an epidemic.	High social impacts during an epidemic. Domestic-animal owners are aware of and could be anxious about the proximity of rabies cases.

Transmission potential (A-H; H-H; A-A; H-A)

See general fact sheet.

Link(s) to climate change: environmental factors with a documented or potential impact on the dynamics of this zoonosis

- Milder climate conditions (shorter, less harsh winters), combined with an increase in land fragmentation due to agricultural or anthropic development could favour raccoon populations, thus increasing their densities and even their distribution range. In the event that raccoon rabies is introduced into Québec, this situation could increase the probability of disease propagation (outbreak further north, number of epidemic outbreaks).

Surveillance or early detection measures in Québec

- Enhanced surveillance in the Estrie and Montérégie regions (Ref. municipalities – websites) under the government plan to combat raccoon rabies. Between 700 and 1000 specimens (especially raccoons, skunks and foxes) are analyzed each year. Specimens come primarily from citizen reports (animals with abnormal behaviour or found dead) or are collected along roadways by technicians certified in enhanced surveillance.
- See general fact sheet.

Prevention and control measures in Québec

- Manual and aerial distribution of vaccine baits in the Estrie and Montérégie regions (website) under the government plan to combat raccoon rabies. The aim is to immunize raccoon populations against RL variant in the areas at greatest risk of raccoon incursions from the United States.
- Annual awareness campaign aimed at citizens living in the surveillance and control areas for the RR variant to inform them how they can contribute to the fight against the RR variant (that is, by reporting to the MFFP any suspect or dead raccoons, skunks and foxes as part of the enhanced surveillance activities, by refraining from handling vaccine baits, and by adopting safe behaviour with regard to wild animals).
- Vaccination awareness of domestic-animal owners.
- See general fact sheet.

Other potential surveillance, prevention and control measures

- Regulation associated with the capture and release of wild animals: vaccination, relocation area.
- Awareness of transporters regarding translocation.
- See general fact sheet.

Knowledge gaps

- Factors influencing immunity in raccoons.
- Optimal vaccine bait density to use in order to immunize a satisfactory proportion of the raccoon population, according to raccoon density.
- Variation in the competition for vaccine baits between raccoons and other wild species, based on type of habitat.
- Factors influencing raccoon's attraction to vaccine baits and how this varies in relation to different habitats (plant phenology, time of year, habitat).
- Factor influencing immunity in skunks.
- Assessment of the risk of animal translocation, and prevention and intervention methods (emergency plan).
- See general fact sheet.

Challenges

- Major impact (human and animal health) in case of an animal outbreak in urbanized and mixed areas.
- Accessibility of rabies pre-exposure vaccination for people at risk of exposure. Workers, such as the staff of animal control companies, must themselves pay the costs of preventive vaccination if they want to get it. These are often low-income independent workers unable to afford this expense.
- Public awareness regarding the behaviour to adopt with regard to wildlife species (e.g., adopting baby raccoons, feeding wild animals, etc.).
- Risk of translocating wild animals by means of transportation or animal adoption.
- See general fact sheet.

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Salmonellosis

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Pathogen: bacterium, *Salmonella* spp. (2000 serotypes, including more than 250 circulating in humans; prevalent types in Québec: (1st) *S. Enteritidis*, (2nd) *S. Heidelberg* (the most invasive and virulent of the three), (3rd) -- *S. Typhimurium*) Excluding*: S. Typhi* and *S. Paratyphi* (responsible for typhoid fever and paratyphoid, serotypes adapted to humans).

Primary animal reservoir in Québec: poultry and swine; *S. Dublin* specifically associated with cattle.

Table 14 Burden of salmonellosis in public health and animal health

Prioritization criteria	Human	Animal
Symptoms or clinical signs/Severity/Morbidity	Gastroenteritis with diarrhea sometimes accompanied by bloody stools; abdominal cramps, nausea, vomiting (sometimes), headache and fever. In rare cases, salmonellosis can progress to septicemia or an extra-intestinal infection. Significant disease morbidity: hospitalizations, work absenteeism, etc.	Varies by serotype and affected animal: often asymptomatic, illness associated most often with diarrhea, more rarely with septicemia, benign to fatal condition.
Duration	Symptom onset from 6 to 72 hours after contact: duration of 4 to 7 days. May occasionally progress to chronic carrier state: persistence of *Salmonella* (weeks, months) without symptoms. Shedding period is variable, lasting up to years.	Shedding from latent carriers may be periodic, intermittent or constant.
Lethality	Generally low lethality, depending on the health condition of the infected individual (higher among young children, older adults or immunocompromised individuals).	Varies by serotype and infected animal: usually < 10%, may reach close to 100% among young animals.
Groups at risk of acquiring the infection and complications	Young children: highest incidence rate. People of low socio-economic status[3]. Complication risks in pregnant women, young children, older adults, people with health problems.	Animals at most risk of being infected and of being the contamination sources for humans: cattle, sheep, goats, swine, poultry or wild birds, dogs, cats, reptiles and aquarium fish.

Table 14 Burden of salmonellosis in public health and animal health (cont'd)

Prioritization criteria	Human	Animal
Incidence over the past 5 years (Québec)	Rate/100,000 and 95% CI (BSV, MSSS, 2016): 2015: 17.63 (16.75-18.56) 2014: 17.98 (17.09-18.92) 2013: 15.02 (14.20-15.89) 2012: 15.75 (14.91-16.64) 2011: 14.64 (13.82-15.50) Average rate 2011–2014: 15.86 (15.43-16.30) Estimated number of annual domestic salmonellosis cases in Canada: 109 000. A large fraction of salmonellosis cases do not seek medical attention because the symptoms may not be severe enough to need a doctor's visit and stool culture. The number of reported cases is likely underestimated (as for other enteric diseases).	The zoonotic agent the most often identified at the MAPAQ laboratories, especially in swine and poultry. The incidence of *S. enteritidis* has decreased in egg-production farming and in hatcheries. *S. Dublin* has emerged in cattle; since its identification in Québec in 2011; its prevalence has been estimated to be 6.4% in dairy cattle herds, according to a prevalence survey conducted in 2015.
Trend	Development of resistance in *S. Typhimurium*, *S. Heidelberg* and *S. Dublin*. Appearance of multi-resistant strains in humans coinciding with the emergence of *S. Dublin* in calves in 2011, whose genetic link was confirmed by genomic analysis[4]; however, very few human cases to date (10 or so per year).	Emergence of serotypes (e.g., *S. Dublin* in 2011 in cattle). Increase in *Salmonella* resistance to certain category 1 antibiotics, observed under the Programme québécois d'antibiosurveillance vétérinaire[5] [Québec's veterinary antimicrobial resistance surveillance program]. However, among the chickens on farms, at slaughter (abattoir) and from the grocery store (retail). sampled under CIPARS[6], a decrease in resistance to third-generation cephalosporins (category 1 antibiotics) was identified between 2013 and 2014. This decrease is associated with the elimination of the preventive use of category 1 antibiotics in chickens, a compulsory measure under the Chicken Farmers of Canada's On-Farm Food Safety Assurance Program since May 15, 2014.

Table 14 Burden of salmonellosis in public health and animal health (cont'd)

Prioritization criteria	Human	Animal
Economic burden	Significant: costs linked especially to hospitalizations and work absenteeism.	Variable, but generally limited. More significant for *S. enteritidis* on farms with laying hens, which must be slaughtered, and for *S. Dublin* in cattle farming. Loss of revenue linked to food recalls.
Social impacts	Low, variability in the knowledge of risks and the application of preventive hygiene measures[3, 7].	Low, but industry concern for public health. Presence of *Salmonella* considered normal in most poultry and swine farming, as well as in their meat products. Serotypes other than *S. enteritidis* and *S. Dublin* are not subject to control, except periodically during disease episodes.

Transmission potential (A-H; H-H; A-A; H-A)

- A-H: Cross-contamination: via carrier or diseased animal (direct contact), via environment contaminated by animal excrement. Risk of transmission limited by aerosolization of contaminated dust (a few metres around a farm). The major vehicles of salmonellosis are food-borne: poultry, beef, eggs and milk products. Other food vehicles have been identified in the context of outbreaks, such as fruit, fresh vegetables, peanut butter, baby formula, cereals and pastries that may have been contaminated through contact with an animal product or a human. Reported outbreaks linked to water or contaminated food (for human consumption). Other existing modes of transmission: ingestion of contaminated water, contact with a reptile, aquarium turtle, rodents or other mammals.
- H-H: Fecal-oral transmission
- A-A : High transmission potential: survival in the environment depends especially on the serotypes, possibly up to several months in food or soil, even several years in excrement (6 years for *S. Dublin*). Some serotypes may be excreted in milk (e.g., *S. Dublin*) or may contaminate the inside of eggs (e.g. *S. Enteritidis*, *S. Infantis*, *S. Hadar*, *S. Hvittingfoss*). The fly is a vector among animals. Reported outbreaks linked to contaminated water or food (for animal consumption).
- H-A : Fecal-oral transmission

Link(s) to climate change: environmental factors with a documented or potential impact on the dynamics of this zoonosis

- Temperature: important factor in the transmission of bacterial agents causing enteritis. *Salmonella* multiplies at room temperature, positive association with rising temperature and the number of outbreaks in the United States, observation of seasonal trend in salmonella infections (infectious peaks during the summer months in Europe and in the spring in Ontario)[1, 8, 9]. Climate change involving an increase in temperatures could influence the number of outbreaks of salmonellosis cases[1, 2].

- Precipitation: positive association with an increase in precipitation (extreme events) in a study led in the coastal areas of the State of Maryland in the U.S. (areas containing the largest number of poultry farms in the State[2]. Soil and water contamination linked to the application of manure/slurry from spring to fall or to the overflow of municipal wastewater; currently, prevalence of 37% in pig slurry pits in the Lanaudière and Montérégie regions.

Surveillance or early detection measures in Québec

- Surveillance for human cases: cases reported to the regional public health authorities by laboratories and entered into the MADO registry.
- Monitoring of trends, detection by molecular characterization of aggregates, and information sharing with the PulseNet Canada surveillance system:
    - Active surveillance program for *S. Enteritidis* (serogroup D) since 1995 at the LSPQ.
    - Active surveillance program for *S. Heidelberg* (serogroup B) since 2003 at the LSPQ.
    - Active surveillance program for *S. Typhimurium* (serogroup B) since 1999 at the LSPQ.
- Laboratory-based surveillance program for *Salmonella* spp. since 1997 at the LSPQ.
- Weekly report on the number of enteric pathogens issued by the LSPQ for the MSSS and the PHAC.
- Laboratory data communicated monthly in the newsletter "Statlabo" issued by the LSPQ.

Animal surveillance:

- Surveillance for animal cases: cases reported to the MAPAQ by laboratories, and some are investigated.
- Enhanced surveillance for S. *Dublin* in cattle.
- Active surveillance program for *S. Enteritidis* in the table egg industry (collaboration between the MAPAQ and the Fédération des producteurs d'œufs du Québec) and in hatcheries (collaboration between the MAPAQ and the CFIA).
- Active surveillance programs for *Salmonella* sp. at slaughter (in abattoirs).

Prevention and control measures in Québec

- Supportive care for humans according to the severity of the symptoms, rehydration if diarrhea, antibiotic therapy if serious infection (e.g., septicemia or arthritis).
- Humans: cleanliness and personal hygiene, sanitation services, protection of food products, milk pasteurization, meat inspection, preventive measure in healthcare facilities.
- Preventive measures recommended by the MSSS and the MAPAQ regarding personal hygiene (hand washing), safe practices when handling and preserving food; environmental health and biosecurity.
- Animals: diet favouring good immunity of young animals (feeding colostrum to calves and reduction of post-weaning stress in piglets), vaccination of animals during disease episodes.
- Control measures in slaughterhouses, especially steam pasteurization in certain slaughterhouses.
- Québec's veterinary antimicrobial resistance surveillance program and compulsory continuing education for veterinarians on the use of antibiotics.

- *S. Enteritidis*: certification program *Contrôle optimal de la salubrité dans la production d'œufs de consommation* offered by the Fédération des producteurs d'œufs du Québec (destruction of positive herds or egg pasteurization).
- Regulatory measures (AOR and WWPR], and certifications (biological, CanadaGAP) governing manure/slurry management, along with the support provided by agricultural advisory services (*services Agri-conseils)* and the *Prime-Vert* program.
- Good management practices for urban biosolids and manure[10].

Other potential surveillance, prevention and control measures

- Use of media (newspapers, radio, television) during outbreaks to remind consumers of preventive measures.
- Irradiation of some foods.

Knowledge gaps

- What is the impact of applying manure and slurry on the crops intended to feed animals or on the animal epidemiological cycle?
- Are the investments required to investigate outbreaks linked to widely eaten foods, known to be contaminated and not usually subject to recall or other interventions (e.g., chicken), associated with an optimal cost-benefit ratio?
- Document the contribution of different food categories to food-borne infections (e.g., fruits, vegetables, nuts).
- Improve our knowledge about source attribution for pro-active surveillance.
- Gain further knowledge about the geomatic and temporal distribution of cases for a better understanding and more effective surveillance.
- The relative magnitude of the different suspected routes of transmission to explain human cases remains largely unknown; is it possible to quantify the proportion of the contamination risk attributable to environmental or food exposure linked to manure and slurry management, compared with other sources of contamination (e.g., municipal wastewater)?
- Document the impact of the Québec Policy on Residual Materials on the risk associated with environmental or food exposure.
- Document the impact of new biofood trends (e.g., biological food) on environmental or food exposure risk.
- What is the expected impact of climate changes on the propagation of antibiotic resistance factors or on the acquisition of this resistance by salmonella infections?
- How applicable is the *Salmonella* surveillance model in the poultry industry to the cattle industry?

Challenges

- The risk associated with the incidence of salmonellosis cases is often linked to the biosecurity measures in place in an industry, which are generally proportional to industries' economic health.
- Salmonellosis outbreaks are subject to investigation in Québec to identify the sources; the documentation of these results in a centralized tool could help improve the attribution of causes during subsequent outbreaks and to target the sources at risk (e.g., it is known that, for young unweaned animals, the primary source of contamination is zoonotic by direct transmission from cold-blooded animals).

- The farm-to-table risk management approach by animal production industry could be the most effective, but contains many challenges associated with knowledge gaps (e.g., documentation of critical points).
- According to the 2013 data from the Canadian surveillance system FoodNet, the presence of *Salmonella* increased in Ontario's surface waters (from 20% to 49% between 2006 and 2013).
- Studies show that the risk of salmonellosis outbreaks varies according to the population's sociodemographic level and place of residence [1, 2]; climate change adaptation measures must take these disparities into account.
- Importation of animals that are carriers of multidrug-resistant *Salmonella*.

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West Nile Virus (WNV)

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Pathogen: West Nile virus.

Primary animal reservoir in Québec: avian (particularly passerines/perching birds, e.g., American robin).

Primary vector in Québec: mosquitoes (*Culex pipiens/restuans*).

Table 15 Burden of WNV in public health and animal health

Prioritization criteria	Human	Animal
Symptoms or clinical signs/Severity/Morbidity	Asymptomatic: 80% symptomatic: 20% flu-like syndrome (headache, weakness, fever, arthralgia, myalgia, chills, rash). Fewer than 1% of the cases develop a neurological impairment (encephalitis, meningitis, meningo-encephalitis, flaccid paralysis); especially in adults older than 50 years (the age limit is 50, 55 or 60 years, depending on the publication).	Generally asymptomatic infections in animals except certain avian species, which present high morbidity and mortality. When present, clinical signs are generally acute to subacute, neurological or non-specific (lethargy, anorexia), sometimes ophthalmic or digestive. Horses: around 20% of infected horses develop the disease (ataxia, aimless wandering, weakness in hind limbs, paralysis in several limbs or lips, fasciculation (or tremors), proprioceptive deficits, sudden death). Wild birds: very variable morbidity. Several species can be asymptomatic carriers (e.g. : American robin), while other birds are highly susceptible to it (crows, some birds of prey).

Table 15 Burden of WNV in public health and animal health (cont'd)

Prioritization criteria	Human	Animal
Duration	Incubation period: from 3 to 21 days. Around 60% to 70% of infection cases with neurological impairment experience medium-to-long-term sequelae (physical and mental, including cognitive impairments [1].	Horses: Incubation period: from 7 to 10 days. The horses condition often improves between the 3rd and 7th day of the disease. If this improvement is significant, 90% of them will be completely cured within 1 to 6 months, while the others will continue to experience neurological sequelae. Wild birds: manifestation of generally acute to subacute clinical signs. However, chronic disease has also been documented.
Lethality	Lethality among cases with neurological impairment: 4%–14%[2].	Variable, depending on the sensitivity of the different animal species. Horses: one third of sick horses die or must be euthanized owing to a severe neurological impairment or to sequelae. Wild birds: particularly high mortality in certain species, especially crows and certain birds of prey.
Groups at risk of acquiring the infection and complications	Humans are accidental hosts. However, people living or staying in endemic areas during the active transmission season, especially those engaging in work-related outdoor activities, are at greater risk of exposure to infected vectors.	Avian reservoir: includes more than 300 species in North America, the most competent being those of the passerine family (the American robin plays a central role in the amplification cycle due to its high viremia and low mortality[3]. Some wild bird species (e.g., American crows, blue jays, raptors[4, 5]) and domestic birds (goslings, quails, partridges, pheasants, ostriches and emus) are highly susceptible. Mammals are accidental hosts of WNV (horses particularly susceptible); crows, rodents, reptiles).

Table 15 Burden of WNV in public health and animal health (cont'd)

Prioritization criteria	Human	Animal
Incidence over the past 5 years (Québec)	Number of WNV cases, rate/100,000 and 95% CI (BSV, MSSS 2016) 2015: 45 cases, 0.52 (0.39-0.71) 2014: 6 cases, 0.07 (0.03-0.16) 2013: 32 cases, 0.39 (0.29-0.55) 2012: 134 cases, 1.66 (1.40-1.96) 2011: 42 cases, 0.51 (0.38-0.70) Average rate 2011–2014: 0.66 (0.57-0,75)	Wild birds: large number of diagnosed cases in 2002 and 2003 among (crows, birds of prey); lull, then an upsurge of cases between 2011 and 2013, peaking in 2012 (44 wild bird cases). Similar trend among horses (9 cases in 2011, 20 in 2012 and 8 in 2013).
Trend	Since the virus was introduced into Québec in 2002: between 0 and 133 cases/year. Predictive climate models based on meteorological factors (heat indexes, duration of cold period, water availability) are difficult to transpose locally due to disparities in certain key factors, especially the abundance and diversity of vectors, microclimate conditions, infection dissemination among the reservoirs, etc.	Horses, sporadic occurrence of cases due to the existence of a vaccine for this species (therefore limited role for sentinel species). Wild birds: occurrence of WNV cases (symptomatic, mortality) temporally preceded human cases in the years following the introduction of WNV; this temporal relationship seems to have been less evident in recent years.
Economic burden	According to a Québec study of the WNV cases from 2012 and 2013, direct and indirect costs linked to disability and mortality were estimated to be $23,521. For cases without neurological impairment, the cost is estimated to be $2,066 per case. The costs for public health interventions to protect the public have yet to be estimated[6].	Limited. Particularly concerns animals in captivity (zoos) and domestic animals.
Social impacts	Particularly for infected people with a neurological impairment (absenteeism, rehabilitation, need for daily support) and in the event of death.	Horses: low to moderate anxiety, given the available preventive measures, especially a vaccine.

Vector characteristics

Mosquito species recognized as being vectors of WNV in North America	About 25 mosquito species have been identified as potential vectors of WNV in North America. Some biting insects other than mosquitoes are also WNV vectors, such as some diptera (e.g., *Hippoboscidae*).
Species of mosquito vectors of WNV present in Québec	Main vectors for transmission to humans in Québec: *Culex pipiens, Cx. restuans, Aedes vexans.* Potential secondary vectors: Coquillettidia perturbans, Culiseta melanura, Cs. inornata, Cx. salinarius, Cx. tarsalis, Ochlerotatus atropalpus, Oc. Canadensis, Oc. cantator, Oc. dorsalis, Oc. japonicus, Oc. triseriatus, Psorophora ferox. In 2015, of all the pools of mosquitoes captured as part of entomological surveillance, that were positive for WNV in Québec, ¾ were composed of the species *Culex pipiens/restuans* (mainly ornithophiles) and ¼ were *Aedes vexans* (mainly mammophiles).
Minimum virus development threshold	Temperature: 14.3 °C Level of viremia of the host necessary for infection in *Culex*: 10^4 –10^5 pfu/ml
Extrinsic incubation period (EIP) above the virus development threshold of 14.3 °C– EIP 50% (degree days).	109 degree days
Hosts	Primary host: birds Accidental hosts: mammals (mainly symptomatic, horses, humans)

Transmission potential (A-H; H-H; A-A; H-A)

- A-H: Vector transmission through the bite of mosquitoes infected by an animal reservoir (bird) is the primary mode of transmission of the virus to humans. Possible virus transmission during animal necropsies (by a contaminated needle or contact between droplets and mucous membranes) has been documented[7].
- H-H: Rare, but possible through blood transfusions, organ donations (kidneys) and congenital infection [8].
- A-A : Vector transmission through the bite of infected mosquitoes, possible direct transmission between birds, and transmission by ingestion among some mammals[9].
- H-A : No, because accidental hosts are considered to be dead ends in the transmission cycle.

Link(s) to climate change: environmental factors with a documented or potential impact on the dynamics of this zoonosis

- Temperature: rising average temperatures associated with the expansion of the distribution range of vector mosquitoes and with the growing speed of virus replication in the vector[10, 11]. Precipitation: associated with the creation of larval breeding sites promoting the development of different species of vector mosquitoes (puddles for the *Aedes* species, stagnant water in catch basins and ditches for the *Culex* species). However, a change in precipitation patterns could also have a negative impact on *Culex* populations: with drought preventing the creation of larval breeding sites in catch basins and with torrential rain washing them out and eliminating them[12].
- Although this is still under debate in the scientific literature, studies show a certain relationship between climate change and a decrease in the biodiversity of birds, which would lead to an increase in the prevalence of WNV in mosquitoes.

Surveillance or early detection measures in Québec

- Surveillance for human cases: cases reported by physicians and laboratories and entered into the MADO registry, which includes asymptomatic cases detected by Héma Québec. Clinical vigilance encourages the detection of cases with neurological impairments and severe non-neurological cases.
- Surveillance for animal cases: cases reported to the MAPAQ by laboratories and through MAPAQ investigations. Mandatory immediate reporting of infectious disease by laboratories to the CFIA. Avian cases identified by the CQSAS.
- Integrated WNV surveillance: includes reported human and animal cases, as well as data from entomological surveillance, implemented during the summer by the MSSS, based on scenarios produced by the INSPQ.
- Integrated WNV vigilance and surveillance system (SIDVS-VNO): computer platform of the MSSS enabling the compilation and real-time dissemination of human cases of WNV, entomological surveillance data and animal cases in Québec for each season, these data can be expressed by administrative health region and broken down by different variables. The integrated data analysis is performed by the INSPQ.

Prevention and control measures in Québec

- Government action plans to protect public health against WNV have specified action strategies since 2002. The 2013-2015 Government Action Plan consists of several interventions aimed at (1) surveillance for the pathogen, vectors and human cases; (2) public awareness of the risk and personal protective measures; and (3) vector control operations in the at-risk areas and at the environmental source. http://publications.msss.gouv.qc.ca/msss/document-000135/.
- Communications to the public concerning personal protective measures to prevent bites, in both humans and susceptible animals.
- Communications to physicians and horse veterinarians at the start of the season to intensify their level of vigilance.
- Vaccination of horses is recommended.
- Since 2003, blood donations tested by Héma-Québec with reverse transcription-polymerase chain reaction (RT-PCR) during the risk period and exclusion of donations, if applicable.
- Living organ donors undergo serological testing by Héma-Québec.

Other potential surveillance, prevention and control measures

- Vector control by eliminating larval breeding sites (peridomestic and larger scale), larvicides and adulticides (not recommended in Québec).

Knowledge gaps

- Human medicine: gain further knowledge about psychosocial factors, human behaviour, pathophysiological mechanisms and potential treatments.
  - How to take into account the gradual immunization of the regularly exposed population in the appearance of symptomatic cases (impact on human epidemiology in the longer term). Seroprevalence studies to be conducted periodically?
  - How to support clinical and laboratory practice with respect to the diagnosis of encephalitis/meningitis during the summer in order to optimize the reporting of WNV cases?
- Veterinary medicine: gain further knowledge about reservoir animals. For example:
  - Which species are the primary reservoirs in Québec? Analyzing the origin of the blood meals of positive mosquitoes could contribute to answering this question.
- Entomology: gain further knowledge about vectors. For example:
  - In which regions is the WNV-infected vector currently found? How will the current dispersion areas of WNV vectors evolve in the coming years? Will these dispersion areas spread north, under the influence of climate change?
  - Can the periodic re-emergence of the virus in the spring be explained by the winter survival of the virus in adult mosquitoes infected with WNV in Québec?
  - Which alternative entomological surveillance methods can be used to characterize the emerging areas of WNV?
  - What is the potentially significant contribution of bridge vectors (e.g., *Ae. vexans*) in the spillover to accidental hosts in Québec?
  - Characterization of mosquito species in Québec (e.g., enumeration of species present, habitats, geographic areas of distribution, vector competence).
- Virology: gain further knowledge about the virus itself. For example:
  - Which factors are involved in the periodic re-emergence of the virus (climate factors, virus importation by migrating birds in the spring, etc.)? What is the impact of virus re-introduction by migrating birds compared with the persistence of the virus in winter? Phylogenetics could contribute to answering this question.
  - What is the role of the viral genome in propagating WNV in North America and particularly in Québec (study in progress by the LSPQ)?
- Risk assessment: identify the factors to be included in a predictive model about the risk associated with WNV to support and direct the interventions for the coming seasons.
- Interventions: gain further knowledge about the effectiveness of the different available interventions, for example:
  - How effective is the use of larvicides for decreasing adult mosquito vector populations in order to reduce the mortality and morbidity associated with WNV in humans?
- Climate: develop knowledge about the role of climate in the issue and about the expected impacts of climate change. For example:
  - About biodiversity and avian reservoirs?

Challenges

- Underdiagnosis of summertime neurological infections (including WNV and other arboviruses): need for awareness and diagnostic support to increase the detection of WNV infections among the cases of neurological disease with an infectious presentation in season.
- Lack of vaccine for humans, no available treatment (only supportive care).
- Socio-economic impacts of neurological sequelae in cases with neurological disease (study in progress at the INSPQ) and life years lost as a result of death.
- Annual variability in the entomological surveillance structure in Québec, thus limiting the monitoring of the spatio-temporal evolution of entomological risk.
- Effectiveness of the communication of recommendations aimed at the at-risk population in order to encourage the use of adequate personal protective measures to reduce exposure: identification of the at-risk population, types of targeted areas (urban, agricultural, mixed), influence of the status of the regions (endemic, at risk of emergence).
- Horses are rarely vaccinated because of the high cost of the vaccine.
- Cases of WNV in wild birds: passive surveillance as part of avian influenza surveillance, under-estimation of bird species affected by the WNV, and limited as a geographic indicator of WVN activity, given the long distances that birds fly.
- Predictive modelling of risk limited by the heterogeneity of environmental and vector factors, and local hosts.
- Impact of urban development on vector mosquito populations (creation of larval breeding sites); considerations and approaches to reverse this trend.

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Conclusion

The Observatoire's collaborative network led to the development of fact sheets on the zoonotic diseases identified as priorities in 2015. This basic portrait presents a knowledge synthesis and will serve as the foundation to document the evolution of zoonoses in Québec in the context of climate change. Essentially based on expert opinion on animal health and public health in Québec, it is a first step in the development of a zoonosis prioritization tool in Québec linked to climate change. This portrait also helps target certain challenges and knowledge gaps, which will ultimately help direct zoonosis research, surveillance, prevention and control efforts in Québec.

This exercise revealed the following main finding: given the current state of scientific knowledge, evidence-based data on the impact of climate change on zoonoses remain limited. This main finding drawn from this exercise deserves further consideration and refinement by the Observatoire. More generally, this document facilitates the Observatoire's ongoing development of a zoonosis prioritization tool, using multiple-criteria decision analysis (MCDA). This rigorous approach to prioritizing zoonoses will more specifically enable the development of criteria and indicators specific to climate change.

The objectives of the 2015 prioritization exercise conducted by the Observatoire were limited to the zoonoses present in Québec or in neighbouring U.S. states or Canadian provinces. Consequently, exotic[1] zoonoses and infections were not included. Nevertheless, it would be important to include these issues in order to anticipate the burden that could be caused by the emergence of these new diseases in Québec.

The Observatoire enables collaboration and synergy between organizations and government departments. This platform becomes indispensable in order to anticipate public health and animal health issues (i.e., zoonoses) linked to climate change. The production of this report has enriched the dialogue between scientific experts and the public health policy makers involved in the management of zoonoses and adaptation to climate change. The members of the Observatoire hope that anyone interested in zoonoses linked to climate change can draw useful information to direct their research, surveillance, prevention and control efforts in Québec.

1 The term exotic refers to "any pathogen or disease that is not endemic to Québec or that represents a threat coming from outside Québec."

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Appendix 1:

Reference sources for the prioritization approach in 2015

Reference sources for the prioritization approach in 2015

Authors	Title	Year	Country	Prioritization objective	Method: Identify criteria	Method: Rank/score criteria	N criteria	Top criteria	N zoonoses	Top zoonoses
V. Ng & J.M. Sargeant	A **stakeholder-informed approach** to the identification of criteria for the priorization of zoonoses in Canada[3]	2012	Canada (ON)	To direct resources for control and prevention of zoonotic diseases	6 focus groups (public, animal health professionals and human health professionals)	Focus groups (score each criterion 1 to 9); mean score used to rank	59	Mortality characteristic s in humans (H), mode of transmission, potential for human-to-human transmission (H)	N/A	N/A
V. Ng & J.M. Sargeant	A quantitative and novel approach to the prioritization of zoonotic diseases in North America : a public perspective[4]	2012	Canada (ON)	To direct resources for control and prevention of zoonotic diseases	(dropped from 59 to 21, which should be quantitatively measurable)	Joint analysis	21	Case fatality in humans (H), incidence of the disease in the last 5 years in humans (H)	62	Nipah virus encephalitis, rabies, Ebola, Marburg, Influenza (H1N1)
N. Stebler et al.	Use of a modified Delphi panel to identify and weight criteria for prioritization of zoonotic diseases in Switzerland[5]	2015	Switzerland	To prevent or reduce **future zoonotic outbreaks**, constant need to invest in research and surveillance programs while updating risk management strategies	Literature review to compile lists of criteria; preference to those criteria that were described in numerous papers and/or assigned a high weighting score. Criteria selected by experts (veterinary)	Expert opinion, 7 veterinarians (Delphi)	28	Severity of disease (H), Incidence/ prevalence of the disease (H), Treatment (H)	16	Avian influenza, bovine spongiform encephalitis, bovine tuberculosis

Reference sources for the prioritization approach in 2015 (cont'd)

Authors	Title	Year	Country	Prioritization objective	Method: Identify criteria	Method: Rank/score criteria	N criteria	Top criteria	N zoonoses	Top zoonoses
C. Logan Rist et al.	Prioritizing zoonoses: a proposed **One Health tool** for collaborative decision-making[6]	2014	United States (CDC)	To help human and animal health agencies to coordinate across sectors in a more effective response to zoonotic diseases, for collaborative surveillance, lab capacity enhancement or other identified activities	Human and animal health agency representatives jointly identify criteria through discussion	Semi-quantitative analytic hierarchy process; each member individually ranks the criteria	5-9	N/A	15-30	N/A
A.H. Havelaar et al.	Prioritizing emerging zoonoses in the Netherlands[7]	2010	Netherlands	To support the development of early warning and surveillance systems of **emerging zoonoses**	N/A	Panel sessions with different professional groups (i.d. control)	7	Probability of introduction, transmission between animals (A), economic damage in animal reservoir (A), animal-human transmission (H), transmission between humans (H), morbidity (H), mortality (H)	86	Avian influenza (H5N1), *Toxoplasma gondii*, Japanese encephalitis virus, *Campylobacter spp*, Mycobacterium bovis

Reference sources for the prioritization approach in 2015 (cont'd)

Authors	Title	Year	Country	Prioritization objective	Method: Identify criteria	Method: rank/score criteria	N criteria	Top criteria	N zoonoses	Top zoonoses
INVS	Definition of priorities in the field of non-food-borne zoonoses (2008-2009)[8]	2008-2009	France	Justify the measures to take in order to **prevent and control the emergence or expansion** of diseases; include anticipated emerging zoonoses **linked to climate change**, environmental changes and behaviour changes.	Ref.: rapport 2000			Incidence (H), global clinical severity (H), mode of transmission to humans (H)		Priority diseases: Lyme borreliosis, chikungunya, dengue fever, Crimean–Congo hemorrhagic fever (vs. significant, moderately significant)
M-F. Humblet et al.	M**ultidisciplinary** and evidence-based method for prioritizing diseases of food-producing animals and zoonoses[9]	2012	Europe	**Surveillance, prevention, control and eradication** of infectious diseases and to target surveillance for early detection of any **emerging disease**	Review of previous priority settings and principles of evidence-based medicine	Expert opinions	57	Epizootic potential (A), case-fatality rate (H), effectiveness of prevention, vaccination, loss of productivity (H), limitation of importation and exportation(A), case-fatality rate, epidemic potential, effect on animal welfare (A) and biodiversity, lower consumption (H)	100	N/A

Appendix 2

Zoonotic diseases pre-selected by the working group as part of the prioritization approach in 2015

Zoonotic diseases pre-selected by the working group as part of the prioritization approach in 2015

	Zoonoses
1	Human anaplasmosis*
2	Babesiosis*
3	Lyme borreliosis/Lyme disease*
4	Chikungunya
5	Tick-borne encephalitis*†
6	Q fever
7	Hepatitis E
8	Psittacosis
9	Tularemia*
10	Rabies (including fox variant)
11	Influenza (H1N1)
12	Listeriosis
13	Influenza (H5N1) (swine, avian)
14	Salmonellosis†
15	*E. coli*† infection (verotoxigenic) (VTEC)
16	Cryptosporidiosis†
17	Eastern equine encephalitis*
18	Giardiasis†
19	Hantavirus pulmonary syndrome
20	Campylobacteriosis†
21	Toxoplasmosis
22	Y. enterocolitica infection†
23	Leptospirosis
24	West Nile virus*†
25	Powassan virus*
26	Anthrax
27	Echinococcosis
28	Toxocariasis
29	La Crosse encephalitis
30	St. Louis encephalitis
31	Showshoe hare virus*
32	Jamestown Canyon virus*
33	Cache Valley virus*
34	MRSA (Methicillin-resistant staphylococcus aureus)

* Zoonoses identified as emerging vector-borne zoonotic diseases of major public health concern in Canada, according to Kulkarni et al., (2015)[10].† Infectious diseases identified by Panic et al. (2013)[11] as having the potential to be affected by climate change in Canada.

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