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Monitoring zoonotic diseases in Québec: overview and avenues for action

EVALUATION

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PROGRAM EVALUATION REPORT

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FOREWORD

The Institut national de santé publique du Québec is the expertise and reference centre in the realm of public health in Québec. Its mission is to support the Québec Minister of Health and Social Services, regional public health authorities, and local, regional, and provincial establishments in the exercise of their duties and responsibilities.

The *Evaluation* collection assembles under a single banner an array of scientific productions that rely on varied evaluative methodological approaches to focus on situations, cases, or specific subjects.

This evaluation report focuses on the state of the monitoring of zoonoses in Québec. It seeks to take stock of the monitoring of tick- and mosquito-transmitted zoonoses and enteric zoonoses carried out in Québec in 2022 and to indicate the preferred avenues for action to optimize the monitoring against a backdrop of climate change. It is not meant to be an exhaustive program evaluation.

The project, funded by the ministère de la Santé et des Services sociaux, is intended for public health authorities.

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GLOSSARY

Monitoring

An ongoing process to assess the health status of a population and its determinants by means of the collection, analysis, and interpretation of health-related data and its determinants in a population that facilitates the dissemination of information adapted to different users and supports decision-making (1–3).

Integrated zoonoses monitoring

Such monitoring integrates and links the collection, analysis, interpretation, and dissemination of human and animal monitoring data to support the analysis of the risk for humans to acquire the disease and decision-making, in particular through the determination of hazard-prone and endemic areas, and the detection of unusual occurrences of emerging zoonotic diseases in human and animal populations (2,4).

Health monitoring

Health monitoring targets early detection of threats to human health to quickly assess health risks or implement control interventions (5).

Climate change

The long-term modification of average weather conditions and the variability of indicators such as temperature, precipitation, and winds (6,7).

The One Health approach

This integrated, unifying approach acknowledges that the health of humans and domestic and wild animals and the environment are closely linked and interdependent and seeks to sustainably optimize human and animal health and ecosystems. To this end, the approach mobilizes the efforts of several sectors and disciplines at the local, national, and international levels (8,9).

ACRONYMS AND ABBREVIATIONS

CFIA	Canadian Food Inspection Agency
CQSAS	Centre québécois sur la santé des animaux sauvages
CSV	California serogroup virus
DSPu	Direction régionale de santé publique (regional public health branch)
EEEV	Eastern equine encephalitis virus
FMV de l'UdeM	Faculté de médecine vétérinaire de l'Université de Montréal
GREZOSP	Groupe de recherche en épidémiologie des zoonoses et santé publique
INESSS	Institut national d'excellence en santé et en services sociaux
INSPQ	Institut national de santé publique du Québec
LSPQ	Laboratoire de santé publique du Québec
MAPAQ	Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec
MELCCFP	Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs
MFFP	Ministère des Forêts, de la Faune et des Parcs[1]
MSSS	Ministère de la Santé et des Services sociaux
ND	Notifiable disease
NML	National Microbiology Laboratory
Observatoire	Observatoire multipartite québécois sur les zoonoses et l'adaptation aux changements climatiques
PEP	Post-exposure prophylaxis
PHAC	Public Health Agency of Canada
PNSP	Programme national de santé publique
SI-GMI	Système informatique de gestion des maladies infectieuses
WEEV	Western equine encephalitis virus
WNV	West Nile virus

[1] Since the appointment in December 2022 of the new Cabinet, the Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs (MELCCFP)(10) has been responsible for the wildlife and parks sectors.

HIGHLIGHTS

Over the past 10 years, an annual increase in the number of reported cases of Lyme disease and two record years of West Nile virus cases have been observed, which denotes a change in the epidemiological situation of zoonoses in Québec. Climate change impacts are also expected to foster the emergence or geographical expansion of other zoonoses. In response to such change, several zoonotic disease monitoring optimization initiatives have been undertaken.

This project proposes an examination of the current state of the monitoring in Québec of tick- and mosquito-transmitted zoonoses and enteric zoonoses and to reflect on avenues for action to optimize such monitoring to guide the implementation of preventive intervention geared to the new climatic and ecological contexts.

- The three-stage project draws inspiration from the environmental scan method, i.e., a synthesis of knowledge to provide an overview; 25 interviews with key informants to pinpoint strong points and opportunities for improvement; and a consensus-building activity to determine avenues for action.
- The findings include an overview in the form of summary tables of the monitoring of tick- and mosquito-transmitted zoonoses and enteric zoonoses in Québec, a list of the main strong points and opportunities for improvement of monitoring according to the key informants; and five key avenues for action to optimize monitoring.
- The main avenues for action retained are to (1) optimize existing monitoring; establish interdepartmental collaboration based on the One Health approach; (3) step up monitoring of vectors or pathogens at risk of emergence; (4) develop and integrate new data sources; and (5) produce and disseminate information geared to intervention.
- This study's findings offer a broad overview and propose avenues for action that would benefit from being prioritized for each category of zoonosis, i.e., tick- and mosquito-generated zoonoses and enteric zoonoses. The avenues for action can ultimately support decision-making by political and health authorities concerning the measures to be adopted to enhance the monitoring of zoonoses already present and at risk of emergence in Québec in the coming years.

SUMMARY

A consultation on the state of zoonoses monitoring carried out in 2011 by the Institut national de santé publique du Québec, in collaboration with the Groupe de recherche en épidémiologie des zoonoses et santé publique, revealed the measures to be emphasized to enhance zoonoses monitoring and early detection of emerging zoonoses in Québec. The epidemiological situation of zoonoses in Québec has changed greatly over the past decade with an annual increase in the number of Lyme disease cases and two record years for West Nile virus cases. Moreover, the documentation is expanding on the impacts of climatic and ecological changes on the epidemiology of zoonoses, thus foreshadowing the emergence or geographical expansion of certain zoonoses. In response to this change, several initiatives have been launched to optimize the monitoring of zoonoses.

More than 10 years later, this project proposes to study the current state of the monitoring of tick- and mosquito-transmitted zoonoses and enteric zoonoses in Québec and to reflect on avenues for action to optimize such monitoring to guide the implementation of prevention initiatives adapted to the new climatic and ecological contexts.

Methodology

The project's conceptualization draws inspiration from the environmental scan method to grasp the context and pinpoint needs to sustain strategic reflection, decision-making, and planning. To this end, the three-stage project combines three data collection methods. It mobilized a broad array of stakeholders representative of the One Health approach,[2] i.e., drawn from the human health, animal health, and environmental health fields and working in different levels of government.

The project comprised the following stages:

- First stage: a synthesis of knowledge to present a broad portrait;
- Second stage: interviews with key informants to pinpoint strong points and opportunities for improvement;
- Third stage: a consensus building activity to determine avenues for action.

[2] See the "Glossary" section.

Findings and discussion

The review of the grey and scientific literature made it possible to present in the form of summary tables a broad portrait of the monitoring of tick- and mosquito-transmitted zoonoses and enteric zoonoses in Québec.

An analysis of the interviews revealed the perceptions of 25 key informants active in the field of zoonoses and the key strong points and opportunities for improvement with respect to monitoring. The list also underpinned discussions during the consensus-building activity.

The consensus-building activity assembled 11 experts from different backgrounds from the zoonoses sector. Together, they discussed the proposed avenues for action in light of the results of the interviews of key informants and pinpointed new avenues for action, either based on their interpretation of the findings or their professional experience. In the wake of the meeting, five key avenues for action were adopted:

1. optimize existing monitoring;
2. establish interdepartmental collaboration based on the One Health approach;
3. step up monitoring of vectors or pathogens at risk of emergence;
4. develop and integrate new data sources;
5. produce and disseminate information useful for intervention.

This study's findings offer a broad overview and propose avenues for action that warrant being specified for each category of zoonosis, i.e., tick- and mosquito-generated zoonoses and enteric zoonoses, since the monitoring activities and challenges differ. This could be done through the existing expert panels.

The study's findings can ultimately support decision-making by political and health authorities concerning the measures to be adopted to enhance the monitoring of zoonoses already present and at risk of emergence in Québec in the coming years.

1 CONTEXT

A consultation on the state of zoonoses monitoring was carried out in 2011 by the Institut national de santé publique du Québec (INSPQ), in collaboration with the Groupe de recherche en épidémiologie des zoonoses et santé publique (GREZOSP) (11). The consultation revealed the preferred measures to enhance the monitoring of zoonoses and early detection of emerging phenomena in Québec.

Since then, public health authorities have sought to optimize monitoring, including the implementation of integrated human and acarological monitoring of Lyme disease that began in 2015. Other initiatives have pinpointed challenges and new avenues for research and intervention, especially the prioritization of zoonoses to be monitored in Québec (12,13) and an overview of the vulnerabilities of workers exposed to zoonoses in the workplace (14). At the same time, the epidemiological situation of zoonoses in Québec has changed greatly over the past decade with an annual increase in the number of Lyme disease cases and two record years for West Nile virus (WNV) cases (15).

The documentation is expanding on the impacts of climatic and ecological changes on the epidemiology of zoonoses. According to the World Health Organization, climate change is posing the greatest threat to human health in the 21st century and increasingly frequent extreme meteorological phenomena such as heatwaves, storms, and floods can exacerbate the burden of zoonoses and foodborne illness (16). What is more, higher temperatures and heavier precipitation can affect the spread of zoonotic pathogens and the geographic distribution and reproduction rate of their vectors and hosts, especially by expanding their distribution area and by promoting their movement to more northerly zones that have become viable (17,18). Human activity can also be affected following longer periods of exposure to vectors or environments that are contaminated by zoonotic pathogens, e.g., an increase in outdoor activities since the climate is more favourable (17,18). Appendix 1 presents a more detailed description of the impacts of climatic and ecological changes on tick- and mosquito-transmitted zoonoses and enteric zoonoses, and their epidemiological status.

In this context, the Ministère de la Santé et des Services sociaux (MSSS) has mandated the INSPQ to again study the state of the monitoring of tick- and mosquito-transmitted zoonoses and enteric zoonoses in Québec and to reflect on avenues for action to optimize such monitoring to guide the implementation of prevention initiatives adapted to the new climatic and ecological contexts. The project is not intended to serve as an exhaustive program evaluation but makes it possible to present a broad portrait of zoonoses monitoring in Québec in 2022.

2 OBJECTIVES

The general objective of this project was to take stock of the monitoring of tick- and mosquito-transmitted zoonoses and enteric zoonoses carried out in Québec in 2022 and to indicate the preferred avenues for action to optimize the monitoring against a backdrop of climatic and ecological changes.

More specifically, from the standpoint of the zoonoses selected, the project sought to:

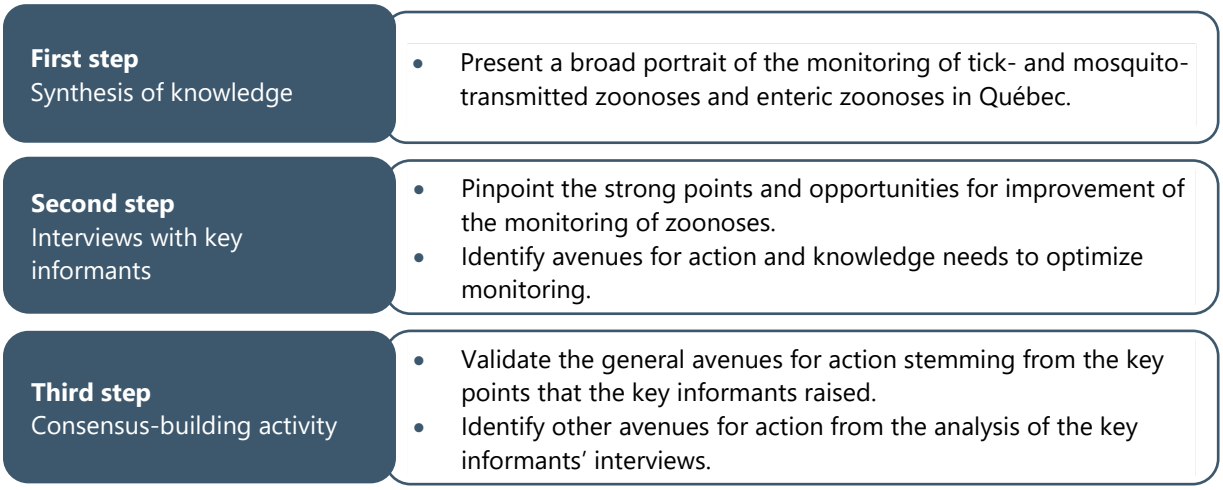
- describe monitoring activities and the public health interventions carried out at the provincial level from 2012 to 2022;
- describe the strong points and opportunities for improvement of monitoring activities;
- propose avenues for action to optimize monitoring and guide the implementation of prevention initiatives and pinpoint knowledge needs.

3 METHODOLOGY

The project's conceptualization draws inspiration from the environmental scan method, which seeks to grasp the context, collect information, and pinpoint needs to sustain strategic reflection and guide decision-making and planning (19). The environmental scan does not provide an in-depth analysis of each program under study but instead facilitates broader research and analysis geared to the available resources to grasp the existing environment (20). It is, therefore, an information gathering process both from the standpoint of internal and external environments that informs and organizes future planning (21,22). The environmental scan also pinpoints issues and questions to be examined in future research (20). To do so, it mobilizes stakeholders and relies on varied data collection methods (19,23).

The three-stage project combines three data collection methods. It relies on a broad array of stakeholders, including key informants and a consultative committee[3] to respond to the objectives (see Figure 1). Reflection on the choice of the stakeholders sought to assemble experts with several years of experience in the public health sector, including professionals and the research and laboratory communities, representative of a One Health approach,[4] i.e., from the fields of human health, animal health, environmental health, and different levels of government. The consultative committee played both an advisory role to plan Stage 2 and served as a focus group in Stage 3.

Figure 1 Project stages and specific objectives



[3] Appendix 4 presents the members of the consultative committee and sections 3.2 and 3.3 indicate their role.

[4] See the "Glossary" section.

3.1 First stage: Synthesis of knowledge

3.1.1 Research question

The literature review sought to answer the following question: What are the key monitoring and public health intervention activities carried out at the provincial level with respect to tick- and mosquito-transmitted zoonoses and enteric zoonoses?

3.1.2 Research strategy

The synthesis of knowledge was based on the systematized narrative review methodology. The literature review, conducted between July 21 and August 26, 2022, comprise publications from scientific and grey literature. For the scientific literature, the Ovid (Medline and Embase databases) and EBSCO (Environment Complete and GreenFile databases) search platforms were used to locate articles published between 2012 and 2022 in English and in French on the monitoring of zoonoses in Québec. The search terms used to identify the relevant publications referred to the key concepts of the research question, i.e., zoonoses (concept 1), monitoring (concept 2), and Québec (concept 3). Appendix 2 presents the database consultation algorithms.

For the grey literature, the research terms used to identify the relevant publications were grouped together under three similar concepts, i.e., the concept of the zoonoses selected (tick-transmitted zoonoses, mosquito-transmitted zoonoses, and enteric zoonoses), the concept of epidemiological surveillance, and the concept of geographic boundaries (province of Québec). A list of terms (keywords) was formulated for each of the concepts and combined using Boolean operators (AND, OR). These research strategies were recopied in the Google search engine. The first 50 results for each combination of research terms were evaluated. Moreover, several Québec government or institutional websites whose expertise is related to the monitoring of zoonoses were consulted, i.e., the MSSS, the Ministère de l'Environnement et de la Lutte contre les changements climatiques, the Ministère des Forêts, de la Faune et des Parcs (MFFP),[5] the Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (MAPAQ), the INSPQ, and the Institut national d'excellence en santé et en services sociaux (INESSS). The keywords zoonoses, ticks, mosquitoes, and enteric were searched for in the publications section or the general search bar. Three unpublished internal INSPQ documents recommended by the project team were also consulted.

3.1.3 Inclusion and exclusion criteria

Inclusion and exclusion criteria were defined to select the publications. Only those published in French and in English for the period between 2012 and 2022 that presented the most recent content were selected for the synthesis. Publications that were updated for this period or whose contents were supplanted by new information were, therefore, excluded. The publications had to

[5] Since the appointment in December 2022 of the new Cabinet, the Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs (MELCCFP)(10) has been responsible for the wildlife and parks sectors.

present descriptive elements of the monitoring of zoonoses in Québec or, more specifically, for each of the themes selected, i.e., tick- and mosquito-transmitted zoonoses and enteric zoonoses, a description of one of the monitoring activities stipulated by the Programme national de santé publique 2015-2025 (Québec's national public health program) (PNSP) (3) (data input, the production of information, the dissemination of information, and support for decision-making), or a description of public health interventions pertaining to zoonoses monitoring at the provincial level.

All told, seven scientific articles, 62 grey literature publications, and one internal INSPQ document were selected. Figure 2 describes the search and selection process pertaining to publications consultation and studies selection.

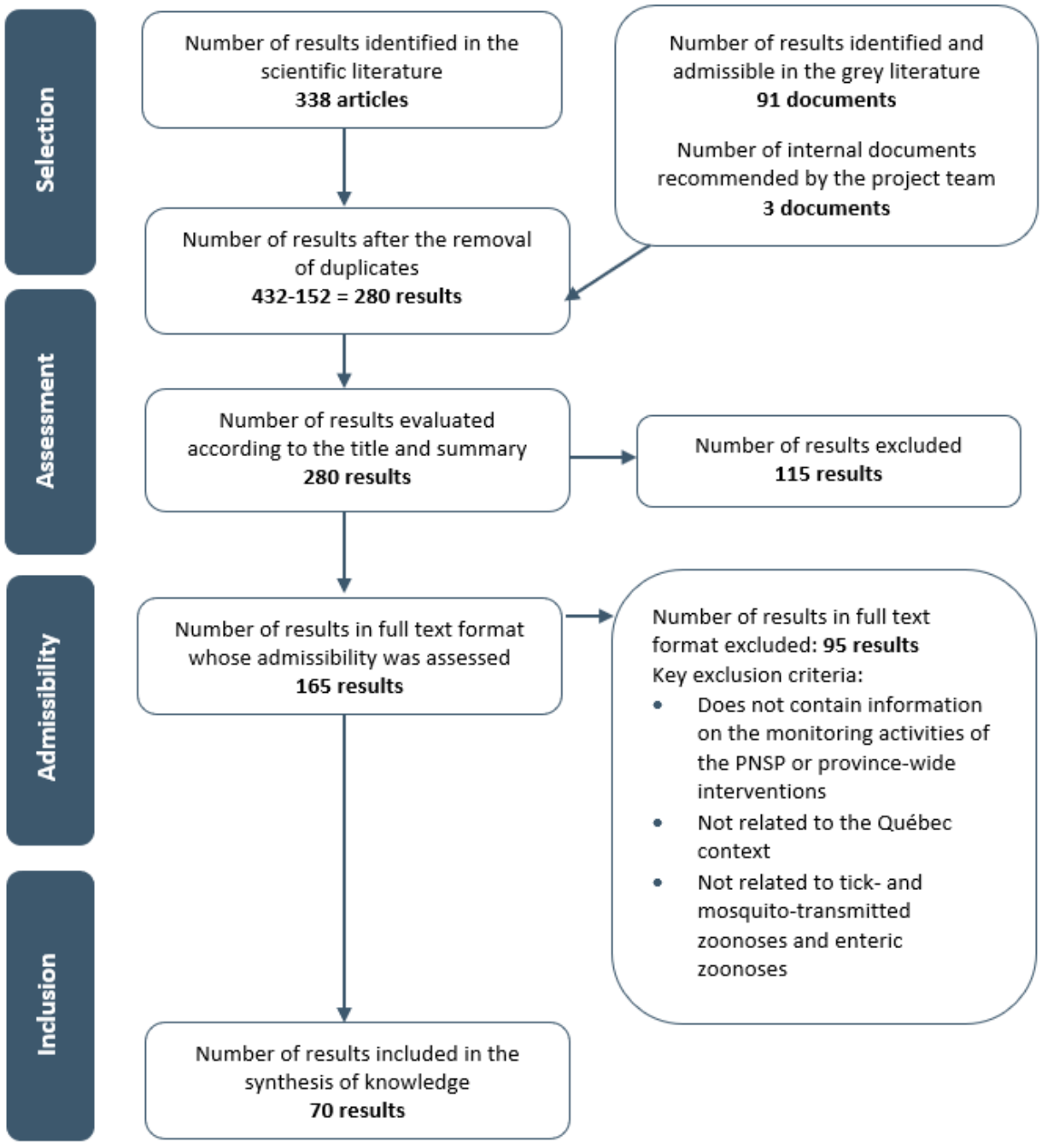
3.1.4 Analysis and synthesis of information stemming from the literature

The descriptions of the monitoring activities identified in the literature were classified by category of zoonoses and by monitoring activities as identified in the PNSP 2015-2025 (3) (see Table 1). The descriptions of province-wide public health interventions identified in the literature were also classified by category of zoonoses.

Table 1 Monitoring activities stipulated by the PNSP 2015-2025

Type of monitoring activities	Description
Data input	Activities that target needs and ensure access to data sources.
Production of information	Includes the analysis and interpretation of data to take stock of the health of the population and its determinants, e.g., trends, variations, action priorities, the detection of emerging problems, prospective scenarios, and follow-up to specific problems.
Dissemination of information	Adaptation and dissemination in a timely manner of the information to address the needs of different users and promote its appropriation.
Support for decision-making	Support to promote the appropriation of the information produced and thus support decision-making to plan and roll out public health services.

Figure 2 **Illustration of the litterature review and selection process**



3.2 Second stage: Interviews with key informants

3.2.1 Selection of the key informants

The key informants were, for a start, chosen in light of their expertise. They had to have a sound knowledge of the monitoring of zoonoses either through their current duties or work experience. To ensure proper representativeness, the project team identified four categories of expertise to represent both the One Health approach of the monitoring of zoonoses and the key monitoring activities presented in the PNSP 2015-2025 (3). The following categories of expertise were selected: (1) veterinary public health and the One Health approach; (2) human public health; (3) diagnostic capacity related to human health; and (4) diagnostic capacity related to animal health and vectors. For each of the themes selected, i.e., tick-transmitted zoonoses, mosquito-transmitted zoonoses, and enteric zoonoses, two or three key informants were identified for each category of expertise. The consultative committee was asked to comment on and validate the profiles of the key informants selected. At the committee's suggestion, a key informant from the Montérégie region was included for the enteric zoonoses theme, and a key informant working in the MAPAQ's laboratories was added.

All told, 25 key informants participated in the semi-structured interviews conducted between October 4 and November 4, 2022. Appendix 3 presents their profile. The confidentiality of the key informants' remarks was assured to enable them to speak freely. To this end, their identity was masked in the documents shared with the consultative committee. Moreover, the data were handled anonymously, and all the interview videos were recorded with access restricted to the project manager and will be destroyed when the study is published.

3.2.2 Interview canvas

The interview canvas used was adapted from the canvas used in the 2011 consultation, which had already been reviewed by an individual experienced in qualitative analyses and pretested (11). Accordingly, the majority of the questions was preserved as was, except for the section on the perception of the impact on zoonoses of climatic or ecological changes since it did not respond to the project's objectives. The interview canvas adopted for this project was divided into three sections: (1) personal information, to create a profile of the respondents; (2) the perception of monitoring activities and province-wide interventions related to the monitoring of zoonoses to pinpoint the strong points and opportunities for improvement and knowledge needs; (3) matching the monitoring activities and interventions with climatic or ecological changes to ensure consideration of ongoing or impending climatic and/or ecological changes. The project team then reviewed the canvas, on which the consultative committee, which added certain clarifications in the examples cited and the questions, commented. Appendix 5 presents the interview canvas.

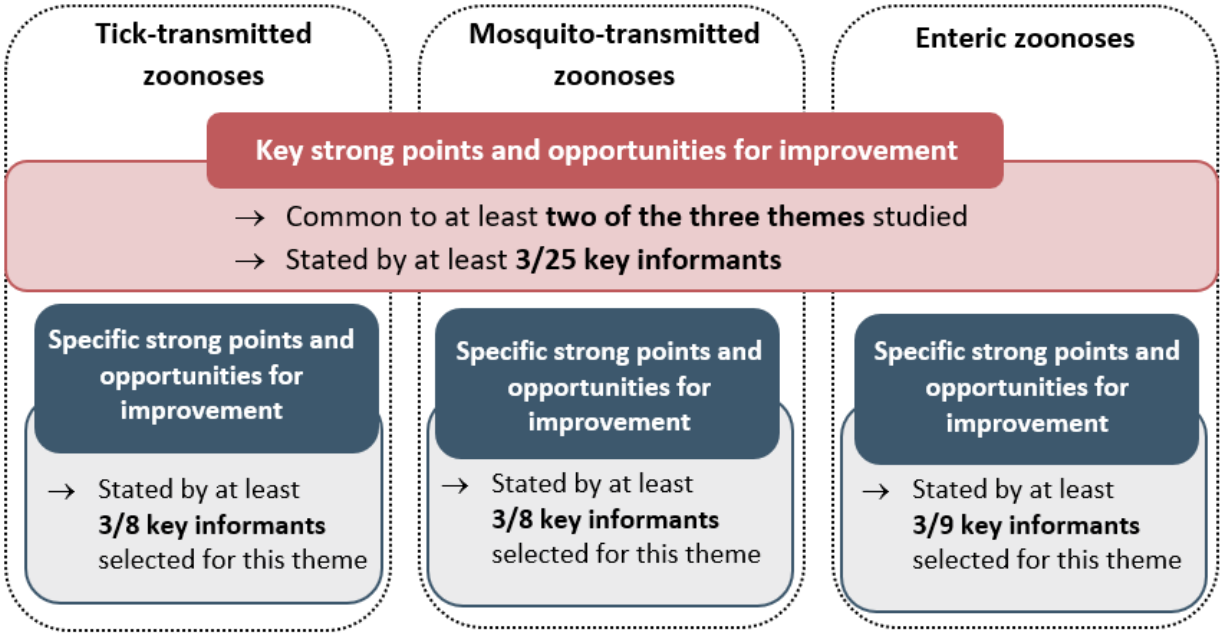
3.2.3 Semi-directed individual interview process

A briefing document (see Appendix 6) was sent to all the key informants before their interviews, which were conducted by videoconferencing on Teams and lasted for between 30 and 45 minutes. Verbal consent was requested at the outset of the interview regarding the video recording and the transcription of the interviews, which all the key informants accepted.

Analysis of the information

Each interview was summarized using handwritten notes, video recordings, and automatic transcriptions. The key ideas expressed were codified to determine concordances and recurrences. The project team set a recurrence threshold of three concordant responses to be selected for each of the themes. Concordant responses common to at least two of the three themes were selected as being the key strong points and opportunities for improvement.

Figure 3 Summary diagram of the analysis of strong points and opportunities for improvement



The key strong points and opportunities for improvement of the monitoring of zoonoses in Québec were first analyzed for the entire array of themes, then specifically for each theme (see Figure 3). They were classified by monitoring activity of the PNSP, i.e., data input, the production of information, the dissemination of information, support for decision-making, and interventions, to which were added province-wide interventions, and synthesized in the findings section.

The knowledge needs that the key informants mentioned were excerpted from the comments collected. Given the extent and heterogeneous nature of the needs mentioned, such needs remain to be addressed in subsequent deliberations and are thus not presented in this report.

3.3 Third stage: Consensus-building activity

3.3.1 Conduct of the activity

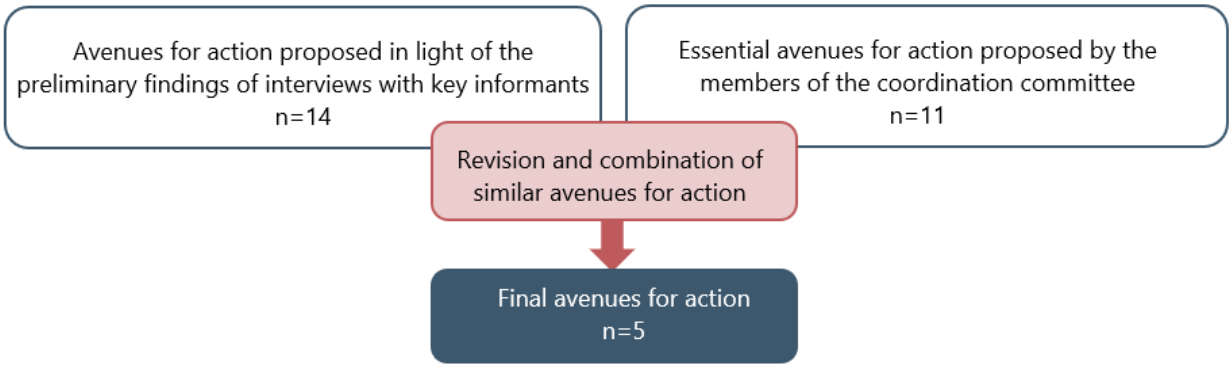
The two-hour consensus-building activity took place on December 9, 2022, by videoconferencing. An email was sent to the members of the consultative committee[6] three days prior to the activity to enable them to prepare for the meeting. The email contained two instructions: (1) examine the general avenues for action proposed based on the preliminary findings of the analysis of the interviews with key informants; and (2) suggest a course of action that they deem essential, either in light of their reading of the preliminary findings concerning the interviews or their knowledge of the monitoring of zoonoses.

The consensus-building activity took place in two stages. The first stage consisted in a summary of the project and the preliminary findings of the key informants' interviews. The presentation was followed by a discussion period to comment on the general avenues for action proposed. The second stage took the form of a round-table forum during which each member proposed an additional course of action, followed by a discussion period on the new avenues for action and the formulation of a summary of the avenues for action retained.

3.3.2 Analysis of the information

The comments received were integrated to adjust and refine the avenues for action proposed in light of the preliminary findings from the key informants' interviews. These avenues for action and the essential avenues for action proposed by the consultative committee were then reviewed to combine similar avenues for action and elaborate a list of final avenues for action pertaining to the monitoring of tick- and mosquito-transmitted zoonoses and enteric zoonoses (see Figure 4).

Figure 4 Summary diagram of the approach to establish the final avenues for action



[6] Appendix 4 indicates the composition of the consultative committee.

4 RESULTS

4.1 Literature review

For each of the themes, i.e., tick- and mosquito-transmitted zoonoses and enteric zoonoses, the results of the literature review are summarized in the form of tables. To present a broad portrait of the monitoring of zoonoses in Québec, each table classifies the information according to the monitoring activities of the PNSP 2015-2025 (data input, production of information, dissemination of information, and support for decision-making) (3). An additional subsection presents the main interventions related to province-wide monitoring.

4.1.1 Tick-transmitted zoonoses

The objective of monitoring tick-transmitted zoonoses is to document the changing risk of contracting the disease in Québec to support the clinical decision-making of physicians and public health authorities in risk management (24). To meet this objective, such monitoring relies principally on three data sources, i.e., the monitoring of human cases, and active and passive acarological monitoring. The document *Portrait de la maladie de Lyme au Québec : 2006-2019* (25) examines changes in the monitoring and epidemiology of Lyme disease and tick-transmitted zoonoses in Québec. Table 2 presents a summary of monitoring activities pertaining to tick-transmitted zoonoses documented in the literature.

Table 2 Summary of monitoring activities pertaining to tick-transmitted zoonoses documented in the literature

Monitoring of tick-transmitted zoonoses		
Data input		
Data sources:		
Monitoring of human cases	Reporting by physicians or laboratories to the regional public health branches concerned. The regional public health branches conduct an epidemiological survey (25).	
Active acarological monitoring	Sampling by the tick dragging method[7] of predetermined sites to collect ticks in the environment in the spring and summer (4).	
Passive acarological monitoring	The voluntary submission to the Laboratoire de santé publique du Québec (LSPQ) of ticks that physicians or veterinarians have found on people or animals (26).	
Databases: The Notifiable disease (ND) reporting system of the MSSS: monitoring data concerning human Lyme disease, babesiosis, Powassan encephalitis, and anaplasmosis cases. (24) Active until 2019: the human data migrated to the infectious disease management information system (SI-GMI) in 2020.[8] MSSS-INSPQ-Université de Montréal database: active acarological monitoring data for 2010, 2011, 2012, and 2014 (25). MSSS-INSPQ database: passive acarological monitoring data, (27) active acarological monitoring data since 2015 - infection status of *Ixodes scapularis* ticks to pathogens causing Lyme disease, anaplasmosis, babesiosis, tick-borne relapsing fever (passive and active monitoring), and Powassan virus (active monitoring) (25,27,28).		
Production of information		
MSSS: Analysis and interpretation of health monitoring data and the monitoring of human cases. (29,30) **INSPQ**: Integrated analysis and interpretation of data pertaining to the monitoring of human cases and passive and active monitoring of ticks and coordination of the deliberations of the Groupe d'experts sur les maladies transmises par les tiques (31).		
Dissemination of information		
Adapted contents	**Dissemination channel**	**Organization**
Monitoring and health monitoring data, anticipated interventions (Flash Vigie) (32)	Newsletter, distribution by email, Web-based repository	MSSS
Data on reported human Lyme disease cases (33)	Web page	MSSS
ND monitoring and surveillance report (29)	PDF report, online	MSSS

[7] The tick dragging method allows for the systematic direct collection of ticks in forests and wooded areas by dragging a white flannel cloth for a determined duration and distance during the ticks' active season between May and October. (24,25)

[8] Human data pertaining to mosquito-transmitted zoonoses and enteric zoonoses also migrated to the SI-GMI in 2020.

Table 2 Summary of monitoring activities pertaining to tick-transmitted zoonoses documented in the literature (continued)

Monitoring of tick-transmitted zoonoses		
Summary of risk-prone regions (34)	Web page	Québec government
Cartography (risk of acquisition and post-exposure prophylaxis (PEP)) (35)	Web page	INSPQ
Annual integrated monitoring findings (35)	Web page	INSPQ
Periodic integrated monitoring findings (25)	PDF report, online	INSPQ
Scientific advisory reports (31,36)	PDF reports, online	INSPQ
Annual tripartite meeting: monitoring findings, planning of monitoring, and interventions (37)	Meetings	MSSS, INSPQ, regional public health branches
Support for decision-making		
Mainly geared to risk management Integrated monitoring: orient interventions through sharing detailed monitoring data by region (35) and the completion of projects that combine monitoring and prevention (38); support clinical decision-making through PEP application zones and risk level by municipality. (25) Reports of the Observatoire:[9] Lyme disease is a zoonosis to be prioritized and identification of monitoring-related challenges (12,13).		
Interventions		
Mainly focused on communications activities Information and awareness-raising concerning individual protective measures (39–41). Awareness-raising tools (general population; (13,24,42) workers (43,44)). Calls for vigilance in the clinical and veterinary sectors (in collaboration with the RAIZO and the FMV de l'UdeM),[10] press releases and media interventions, alert on the Canadian Network for Public Health Intelligence (32). **Other possible interventions** Miticide treatment of rodents: research under way in Québec (45,46). Development of parks and places of public use (24,39–41).		

[9] Observatoire multipartite québécois sur les zoonoses et l'adaptation aux changements climatiques.

[10] RAIZO: Réseau d'alerte et d'information zoosanitaire; FMV de l'UdeM: Faculté de médecine vétérinaire de l'Université de Montréal.

4.1.2 Mosquito-transmitted zoonoses

The monitoring of mosquito-transmitted zoonoses in Québec hinges primarily on the WNV and neuroinvasive arboviruses,[11] which are NDs (48). WNV has since 2003 been subject to integrated monitoring (32), which seeks to promptly identify in time and space areas at risk of the transmission of WNV to protect the health of the population (32) and is based on three data sources, i.e., human cases monitoring, passive animal monitoring (horses and birds), and entomological monitoring (mosquitoes; suspended between 2007 and 2012, then in 2022) (15). The monitoring of other mosquito-transmitted zoonoses is conducted principally by human surveillance (California serogroup virus [CSV], or a combination of human and animal surveillance (Eastern equine encephalitis virus [EEEV]). (49–52) The document *Portrait de la maladie de Lyme au Québec : 2003-2018* (15) examines changes in the monitoring and epidemiology of WNV. Table 3 presents a summary of monitoring activities pertaining to mosquito-transmitted zoonoses documented in the literature.

Table 3 Summary of monitoring activities pertaining to mosquito-transmitted zoonoses documented in the literature

Monitoring of mosquito-transmitted zoonoses	
Data input	
Data sources:	
Monitoring of human cases (NDs)	Reporting by physicians or laboratories to the regional public health branches concerned. The regional public health branches conduct an epidemiological survey (13). Reporting by Héma-Québec of WNV cases detected among donors (49,53); Héma-Québec nurses can conduct epidemiological studies by delegation (54).
Animal surveillance	Reporting by veterinarians and animal health laboratories of suspected or confirmed cases of WNV or EEEV/Western equine encephalitis virus (WEEV)[12] to the RAIZO in the MAPAQ and the Canadian Food Inspection Agency (CFIA) (57,58). The regional public health branches concerned and the Direction de la vigie sanitaire in the MSSS are notified by the MAPAQ, which investigates if necessary (49). Sharing of information on infected domestic animals supported by the *Entente de collaboration et communication concernant la prévention, la vigie, la surveillance et le contrôle des zoonoses* (49). Detection of WNV by the Centre québécois sur la santé des animaux sauvages (CQSAS) in wild birds collected in the context of avian influenza monitoring programs and causes of wildlife mortality (49).
Entomological surveillance	Mosquito trapping during the summer by a firm mandated by the MSSS on predetermined sites. The mosquitoes were submitted to the LSPQ for analysis (49).

[11] Mosquito-transmitted neuroinvasive arboviruses are mainly caused by the following viruses: Eastern equine encephalitis, Western equine encephalitis, St. Louis encephalitis, Japanese encephalitis, and California serogroup virus, e.g., Jamestown Canyon and Snowshoe Hare (47).

[12] WNV and EEEV/WEEV are immediately notifiable animal diseases under the responsibility of the CFIA (55,56).

Table 3 Summary of monitoring activities pertaining to mosquito-transmitted zoonoses documented in the literature (continued)

Monitoring of mosquito-transmitted zoonoses

Databases:

Système intégré de données de vigie sanitaire (SIDS-VNO): a centralized platform that facilitated the compilation and real-time dissemination of human, animal, and entomological monitoring and cartography (13,49,59). Data on human cases migrated to the SI-GMI in 2020, which ended the integration of data into a centralized system (5).

SI-GMI: data on NDs (human WNV cases and neuroinvasive arboviruses) (60).

Animal databases: sharing through collaboration with the MAPAQ and the CQSAS (60).

MSSS-INSPQ entomological databases: identification of the mosquito species collected, the place and date of collection, and the WNV infection status (15). Data collection began in 2000 and was interrupted from 2007 to 2012 because of the limited number of human cases reported, then resumed from 2013 to 2021 (5,15,49,61). It was suspended in 2022 to review the objectives (62).

Production of information

MSSS: Analysis and interpretation of health monitoring data and the monitoring of human cases (30,32,50).

INSPQ: Analysis and interpretation of integrated WNV monitoring data; analysis and interpretation of available data for other mosquito-transmitted zoonoses, e.g., CSV, WEEV, and VEEE and coordination of the deliberations of the Groupe d'experts sur les maladies transmises par les moustiques (15,49,51,63,64).

Réseau équin du RAIZO: Analysis of WNV and EEEV monitoring data in horses for the purpose of follow-up and recommendations concerning the implementation of public health measures or management with respect to animal health (58).

Dissemination of information

Adapted contents	Dissemination channel	Organization
Flash Vigie: Monitoring and health monitoring data, anticipated interventions (32,48,65)	Newsletter, distribution by email, Web-based repository	MSSS
Data on reported human WNV cases (66)	Web page	MSSS
ND monitoring and surveillance report (29)	PDF report, online	MSSS
Annual integrated monitoring findings (60)	Web page	INSPQ
Periodic integrated monitoring findings (15)	PDF report, online	INSPQ
Scientific advisory reports (64,67,68)	PDF reports, online	INSPQ
Annual tripartite meeting: monitoring findings, planning of monitoring, and interventions (37)	Meetings, and so on	MSSS, INSPQ, regional public health branches

Support for decision-making

Integrated monitoring: Facilitates the acquisition of knowledge mainly on the epidemiology of WNV, such as the geographic and seasonal risk of acquisition, and seeks to orient prevention interventions. (32)

Reports of the Observatoire: Zoonoses to be prioritized (WNV and EEEV)[13] and identification of challenges (12,13).

[13] It should be noted that the zoonosis prioritization exercises that the Observatoire conducted occurred between 2015 and 2017 and the epidemiological situation may have evolved.

Table 3 Summary of monitoring activities pertaining to mosquito-transmitted zoonoses documented in the literature (continued)

Monitoring of mosquito-transmitted zoonoses
Interventions
Province-wide intervention plan
The MSSS drafted and implemented an intervention plan to protect Quebecers from WNV between 2013 and 2015 following a surge in human cases (54).
The complex ecology of the WNV transmission cycle appears to limit the capacity of monitoring to anticipate the intensity of a season (32,69) and thus hardly guides risk management to prevent human cases (32). The INSPQ is currently analyzing the integrated monitoring strategy in order to propose adjustments to meet these needs (32).
Communications activities
The general population: Information and awareness-raising on the health risks and individual safeguards to be adopted by the general population (32,32,48), awareness-raising tools such as a poster and a leaflet (70), and information on the measures to adopt such as the elimination of stagnant water to reduce the number of mosquitoes in the environment (71).
Human and animal health professionals: Awareness-raising activities to bolster vigilance and the detection of infections (13,30,48).
Other possible interventions
Larviciding: No province-wide larviciding has occurred since 2015 (72).

4.1.3 Enteric zoonoses

The monitoring of enteric zoonoses is not subject to province-wide integrated monitoring although several organizations are contributing to monitoring one or more enteric zoonoses. The monitoring of human enteric zoonoses cases relies mainly on the notifiable disease (ND) surveillance system and certain monitoring programs in respect of which the MSSS mandated the LSPQ in the 1990s. The reported cases thus correspond to individuals who consulted a physician and for which a laboratory analysis confirmed the presence of a pathogenic agent (73) or an epidemiological link with an outbreak. Botulism, brucellosis, Q fever, epidemic gastroenteritis of undetermined origin, foodborne and waterborne illness, which can be caused by enteric zoonoses, and trichinosis are NDs (47). However, the regional public health branches do not conduct systematic epidemiological investigations for the entire array of reported cases. Furthermore, enteric zoonoses can lead to outbreaks that are detected either through specific monitoring programs of certain pathogens subject to real-time province-wide monitoring, e.g., labovigilance programs for *salmonella spp.* (74), *Listeria monocytogenes*, (75) and Shiga toxin-producing *E. coli* bacteria, including O157 (73)); by means of alerts from other public health organizations in Québec, Canada, or in border states through the Canadian Network for Public Health Intelligence (CNPHI) or other alert networks, or public complaints to the food inspection service of the MAPAQ (76). *Portrait des zoonoses entériques au Québec, 2000-2017* (73) explains in detail changes in reported cases and spatial and temporal trends respecting enteric zoonoses. Table 4 presents a summary of monitoring activities pertaining to enteric zoonoses.

Table 4 Summary of monitoring activities pertaining to enteric zoonoses documented in the literature

Monitoring of enteric zoonoses	
Data input	
Data source:	
Monitoring of human cases (NDs)	Reporting by physicians or laboratories to the regional public health branches concerned. The regional public health branches prioritize certain infections for epidemiological investigations pursuant to an agreement with the MSSS, e.g., Verocytotoxin (VT)-producing E. coli, invasive listeriosis, botulism, and giardiasis diagnosed in children 5 years of age or under. Any other case can be investigated but the scope of the investigations can vary from one region to the next (73).
Monitoring of foodborne illness	The MAPAQ monitors cases (77), in collaboration with its Laboratoire d'expertises et d'analyses alimentaires (78), the MSSS, the regional public health branches concerned, the LSPQ and the INSPQ, the CFIA or other organizations according to needs, following the provincial coordination described in detail in the Modalités québécoises d'intervention lors de toxi-infections d'origine alimentaire et de zoonoses (76,79).
Monitoring of non-foodborne enteric zoonoses, e.g., bathing water and farm animals	The same case monitoring procedures as for foodborne illness. Reported animal cases, e.g., brucellosis, Q fever, campylobacteriosis, and salmonelloses, can lead to investigations conducted by the MAPAQ (79).
Detection of outbreaks	Labovigilance programs (*salmonella spp.* (74), *Listeria monocytogenes* (75), and Shigatoxin-producing E. coli bacteria including, including 0157 (73), real-time notification of the regional public health branches and Bureau de vigie in the MSSS by the LSPQ, (79), alerts through RCRSP, PulseNet Canada,[14] and other networks.
Other one-off projects	Enhanced cryptosporidiosis monitoring project conducted by the LSPQ from 2016 to 2017 (13,81), monitoring of campylobacter in animal livers conducted by the MAPAQ from 2014 to 2017 (82), or active E. coli monitoring programs in slaughterhouses (13)**.**
Databases: SI-GMI: data on NDs (botulism, brucellosis, Q fever, epidemic gastroenteritis of indeterminate origin, and foodborne and waterborne illness (47). MAPAQ databases: data on foodborne illness (73,83). Registre central des éclosions: data on outbreaks from varied sources and modes of transmission, including enteric zoonosis outbreaks (83). Information sharing during investigations or pursuant to agreements and strategies, e.g., the *Entente de collaboration et communication concernant la prévention, la vigie, la surveillance et le contrôle des zoonoses* (79), *Stratégie québécoise sur la santé des animaux sauvages*) (84).	

[14] The LSPQ is collaborating on the PulseNet Canada, managed by the National Microbiology Laboratory (NML), which monitors foodborne illness caused by certain bacteria and ascertain whether they are linked to the same source of contamination by means of genomic methods (association of cases by DNA sequencing) (76,80). If two or more cases are associated, an investigation will be conducted to determine the potential source of contamination (73,76).

Table 4 Summary of monitoring activities pertaining to enteric zoonoses documented in the literature (continued)

<table>
<tr><th colspan="3">Monitoring of enteric zoonoses</th></tr>
<tr><th colspan="3">Production of information</th></tr>
<tr><td colspan="3">MSSS: Analysis and interpretation of health monitoring data and the monitoring of human cases (42,86,89).
INSPQ: Descriptive analysis of spatial and temporal trends and coordination of the deliberations of the Groupe d’experts sur les zoonoses entériques. (73)
MAPAQ: Analysis and interpretation of foodborne illness (86).</td></tr>
<tr><th colspan="3">Dissemination of information</th></tr>
<tr><th>Adapted contents</th><th>Dissemination channel</th><th>Organization</th></tr>
<tr><td>Flash Vigie: monitoring and surveillance data, status reports, and recommendations (86,89)</td><td>Newsletter, distribution by email, Web-based repository</td><td>MSSS</td></tr>
<tr><td>ND monitoring and surveillance report (29)</td><td>PDF report, online</td><td>MSSS</td></tr>
<tr><td>One-off monitoring findings overview (31)</td><td>PDF report, online</td><td>INSPQ</td></tr>
<tr><th colspan="3">Support for decision-making</th></tr>
<tr><td colspan="3">The monitoring of enteric zoonoses reveals trends, detects outbreaks, and facilitates epidemiological studies to pinpoint and eliminate the source when possible.
Deliberations of the Observatoire: zoonoses to be prioritized (botulism, campylobacteriosis, cryptosporidiosis, E. coli, Q fever, giardiasis, salmonellosis, and listeriosis) and identification of challenges (12,13).</td></tr>
<tr><th colspan="3">Interventions</th></tr>
<tr><td colspan="3">Management of outbreaks
Includes the investigation and implementation of adequate control measures and communications activities by the organizations involved (13,79).
Recommendations
Both the MAPAQ and the MSSS can communicate good hygiene and health practices, as needed. Moreover, preventive recommendations are available on their websites (77,87).
Public health authorities can issue recommendations related to drinking water and recreational waters, e.g., boil water advisories and showering before entering public swimming pools (13).
Implementation of measures
The MAPAQ can recommend preventive or control measures in the context of investigations (13).
Government authorities can implement regulatory measures to regulate good practices and thus limit the risk of contamination, e.g., the Agricultural Operations Regulation and the Regulation respecting the quality of drinking water (13).</td></tr>
</table>

4.2 Interviews with key informants

In the wake of the overview of the monitoring of zoonoses in Québec obtained from the literature review, the interviews with key informants revealed the strong points and opportunities for improvement respecting such monitoring. An analysis of the responses of the 25 key informants revealed several similarities and recurrences. The main strong points and opportunities for improvement common to the three monitoring themes studied are first presented, then the points specific to each theme are explained in detail.

4.2.1 Results common to the three themes

Table 5 presents the key strong points and opportunities for improvement with respect to the monitoring of zoonoses in Québec common to the three themes. Generally speaking, the key strong points are the surveillance systems and collaboration. The main opportunities for improvement are the detection of emergence and the need to access and integrate data from varied sources.

Table 5 Key strong points and opportunities for improvement with respect to the monitoring of zoonoses in Québec according to the perceptions of 25 key informants, by monitoring activity

Strong points	Opportunities for improvement
Data input	
• Effectiveness of the ND system: classification of cases according to precise criteria, additions from the ND system in light of epidemiological change, e.g., anaplasmosis and babesiosis, clearly defined procedures governing epidemiological surveys • The current reporting system allows for the detection of certain zoonoses included in human or animal surveillance, e.g., anaplasmosis and avian influenza • Strong collaboration between the organizations, above all concerning public human and animal health, e.g., strategic agreements[15] and in interaction with the LSPQ and the MAPAQ during epidemiological investigations	• Uncertain funding for monitoring activities: there is a risk of a gap in historic continuity for certain data and a risk of a loss of expertise • The revision of certain nosological definitions does not reflect epidemiological trends or the new practices and tests available • The prioritization of investigations to be conducted and revision of the questionnaires to optimize data collection • The establishment of specific monitoring or laboratory tests for certain vectors or pathogens at risk of emergence, e.g., Usutu virus, leishmaniasis, ehrlichiosis, *Borrelia miyamotoi* (an acarological test is available but there is no test for humans) • Increase laboratory capacity to detect emergence, e.g., analysis of greater numbers of vectors to detect pathogenic agents

[15] The agreement on foodborne illness and the *Stratégie québécoise sur la santé des animaux sauvages* were cited as examples.

Table 5 Key strong points and opportunities for improvement with respect to the monitoring of zoonoses in Québec according to the perceptions of 25 key informants, by monitoring activity (continued)

Strong points	Opportunities for improvement
Production of information	
• The presence and ongoing funding of expert panels focusing on ticks and mosquitoes at the INSPQ ensures the continuity of monitoring activities • Laboratory expertise and new technologies used (genomics) • Integrated monitoring of tick- and mosquito-transmitted diseases	• **Priority focus**: visualization of the geographical spread and follow-up to the epidemiology of the provinces and border states to anticipate emergence • Possible conflicts of interest in expert panels, e.g., financial interests and the presence of decision-makers who can bias the scientific approach • Access to additional data, especially environmental data, e.g., water quality, and climatic data, e.g., temperature and humidity • Access to fine spatial scale data • The need for a more flexible, complete information system: data integration (NDs, aggregate coding) at a given site to facilitate the analysis, interpretation, and planning of intervention during emergences or outbreaks (a tool that incorporates several data sources) • The integration of innovative monitoring data sources such as *etick* to broaden the geographical coverage and explain in detail on a finer spatial scale
Dissemination of information	
• Rapid information sharing between professionals and experts when an emerging situation is observed • Access to data by means of ND files, status reports, and the Infocentre[16] • Information sharing and collaboration facilitated by the Observatoire	• Collaboration that hinges on the knowledge and responsiveness of individuals in place and is not structured by formal agreements between the government departments concerned, the laboratories, and the research community
Support for decision-making	
The experts in place facilitate rapid information sharing during an emergence situation	• Modelling and predictions to anticipate needs and plan the intervention • Initiatives that rely on the One Health approach, e.g., a permanent committee that encompasses animal and human health and the environmental sciences to share information and develop knowledge (frameworks, strategies, resources) and facilitate the integration of the approach in the regional public health branches
Interventions	
No point reported.	

[16] The Infocentre de santé publique is a limited-access portal that disseminates statistics from several data sources.

4.2.2 Outcomes specific to tick-transmitted zoonoses

In addition to the outcomes common to the three themes, several strong points and opportunities for improvement specific to the monitoring of tick-transmitted zoonoses were reported. Table 6 indicates the convergent points for this theme.

Table 6 Strong points and opportunities for improvement specific to the monitoring of tick-transmitted zoonoses

Strong points	Opportunities for improvement
• Access to historic data for passive acarological monitoring • Annual update of integrated monitoring data • Access to mapping of risk of acquisition and other useful information • Annual meeting of the MSSS, the INSPQ, and regional public health branches to provide information for the forthcoming season • Enhanced clinical practices through the deliberations of the INESSS	• A matter of priority: the need to detect the emergence of new tick-transmitted zoonoses • Maintenance of acarological monitoring in endemic regions to visualize the progress of vectors and pathogens • Maintenance of active acarological monitoring for sentinel sites to avoid interrupting the continuity of monitoring and facilitate retrospective analysis • The inclusion of other emerging pathogens in passive monitoring and updating of the list of pathogens monitored according to possible emergences • Access to a directory of suspected cases of tick-transmitted diseases to link eventual similar cases and detect emergences • Evaluation of the monitoring program to optimize it • The inclusion of climate change-related issues in monitoring objectives

4.2.3 Outcomes specific to mosquito-transmitted zoonoses

Several specific suggestions were made with respect to mosquito-transmitted zoonoses focusing, by way of an example, on early detection. Table 7 indicates the convergent points raised by the key informants.

Table 7 Strong points and opportunities for improvement specific to the monitoring of mosquito-transmitted zoonoses

Strong points	Opportunities for improvement
• Sound expertise exists • The *Stratégie québécoise sur la santé des animaux sauvages* facilitates the establishment of targeted monitoring programs such as WNV through opportunistic sampling • Data sharing with the regional centres of the Canadian Wildlife Health Cooperative[17]	• The use of other data sources to ensure early detection of WNV and other mosquito-transmitted zoonoses, e.g., domestic pets and Héma-Québec for diseases other than WNV • Evaluation of entomological surveillance • Overview and monitoring of neurological syndrome cases of undetermined aetiology • Prospective surveillance for the entomological section (expand the territory and type of territory monitored, e.g., wetlands as opposed to urban areas) • Collaboration between the infectious diseases, environmental health, occupational health, and prevention promotion teams in the regional public health branches to facilitate investigations and planning interventions

4.2.4 Outcomes specific to enteric zoonoses

The key informants consulted raised several opportunities for improvement focusing on regional epidemiological investigations focusing specifically on enteric zoonoses. Table 8 indicates the entire array of convergent points that they raised.

Table 8 Strong points and opportunities for improvement specific to the monitoring of enteric zoonoses

Strong points	Opportunities for improvement
• Collaboration with the other Canadian provinces and the federal government, e.g., FoodNet[18] and PulseNet[19] • Availability of training in field epidemiology	• Regional epidemiological investigations: a limited number of investigations are conducted, resources and trained professionals are lacking, investigations are delayed before environmental sampling, which hampers the detection of sources, regional public health branch teams work in hierarchical structures, which delays investigations

[17] The Canadian Wildlife Health Cooperative is a Canada-wide network of partners and collaborators that assembles researchers and experts in the realm of wildlife health and enables them to access a shared database (88).

[18] Foodnet is an infectious enteric disease monitoring initiative coordinated by the PHAC that facilitates the networking of sentinel sites to attribute the sources of such diseases. The sentinel site adopted in Québec is that of the Montérégie health region (89).

[19] The LSPQ collaborates on the PulseNet Canada network, managed by the NML, which monitors foodborne diseases caused by certain bacteria and detects whether they are associated with the same source of contamination by means of genomic methods (the association of cases by DNA sequencing) (76,80). If two or more cases are associated, an investigation is conducted to determine the potential source of contamination (73,76).

4.3 Consensus-building activity

The consensus-building activity assembled the consultative committee to discuss the avenues for action proposed in light of the outcomes of the interviews with key informants, then identify new avenues for action. In the wake of the meeting, five key avenues for action were adopted: The "Discussion" section explains them in detail.

5 DISCUSSION

5.1 Key observations

The literature review provided a broad portrait of the monitoring of tick- and mosquito-transmitted zoonoses and enteric zoonoses in Québec. It describes the monitoring of zoonoses in Québec over the past 10 years, e.g., integrated monitoring of Lyme disease, the first enteric monitoring overview, and numerous related productions, and adjustments to its planning and rollout, e.g., the addition of the pathogens monitored, and the resumption and suspension of entomological surveillance. The consultation conducted in 2011 (11) on the monitoring of zoonoses identified 10 key avenues for action, which have been implemented over the past decade. Appendix 7 examines in detail a comparison of the avenues for action proposed in 2011 and the monitoring of zoonoses under way in 2022.

The interviews with key informants revealed the perceptions and experiential knowledge of the experts and professionals who participated in them. Several strong points were emphasized, as well as several opportunities for improvement. The detection of emergence and access to data are two preponderant concerns, as well as the pooling of expertise and knowledge useful for intervention. The key informants' responses sustained the consultative committee's reflections in order to identify avenues for action.

5.2 Avenues for action

Five key avenues for action were identified in the wake of the review and amalgamation of the avenues for action proposed in light of the analysis of the interviews with key informants and those proposed during the consensus-building activity. The avenues for action are numbered but have not been prioritized.

1. Optimize existing monitoring

The optimization of the existing monitoring of tick- and mosquito-transmitted zoonoses and enteric zoonoses would both maintain the existing strong points and enhance certain elements. To this end, consideration should be given to:

- maintaining and perpetuating existing monitoring activities and collaboration, i.e., the presence of expert panels, integrated monitoring and robust, sustained collaboration with the animal health sector (the MAPAQ, the MELCCFP, and the FMV at the UdeM) ensure effective monitoring activities, especially by facilitating information exchanges;

- enhance the existing reporting system: the ND system facilitates the collection of data useful for monitoring and the detection of certain emergences. However, it would be worthwhile to recentre epidemiological investigations on monitoring-related objectives to simplify data collection by relying on priority information, e.g., reduce the number of questions and harmonize the questionnaires between the regions. It also seems necessary to reflect on the updating of nosological definitions in light of new practices or the diagnostic tests available while minimizing interruptions over time in data comparisons.
- Optimize the use of data already collected and accessible: some of the available data could be analyzed and interpreted differently, e.g., it would be possible with the data available to calculate the positivity rate of human cases according to the number of tests conducted in a given region or be shared or disseminated in such a way as to better respond to needs.

2. Establish interdepartmental collaboration based on the One Health approach

Sustained by an agreement and long-term funding, such collaboration would assemble experts from the human health, animal health, and environmental sciences sectors. It would facilitate information and data sharing to pool knowledge with respect to planning and prioritization. Moreover, such collaboration would foster the maintenance of a rapid emergency response capacity since the expertise would already be coordinated. It is proposed that existing structures be emphasized such as the Observatoire and participation in federal government initiatives that rely on collaboration centred on the One Health approach, e.g., avian influenza and FoodNet.

3. Step up monitoring of vectors or pathogens at risk of emergence

Vectors such as ticks have the potential to transmit several pathogens and a new pathogen could thus emerge in a region where Lyme disease is endemic and there is a high density of ticks. Other vectors or pathogens at risk of emergence through geographical expansion or importing should also be subject to specific monitoring, e.g., the Usutu virus and Leishmaniasis. Certain enteric zoonoses that are already endemic also pose a potential for emergence through outbreaks related to specific conditions such as improper handling and conservation errors. To detect and properly monitor such emergences, the maintenance and enhancement of the LSPQ's diagnostic capacity would facilitate greater numbers of analyses and monitoring of new laboratory tests and technologies that may become available with respect to pathogens at risk of emergence. The possibilities of ongoing passive monitoring of animals with respect to certain pathogenic agents that are not notifiable among humans could be explored.

4. Develop and integrate new data sources

The development and integration of new data sources seems essential to detect and monitor emergence both from the standpoint of the introduction of new vectors or pathogens and the geographical expansion of certain known vectors and pathogenic agents that they can transmit, or during investigations of outbreaks. Several development opportunities are being proposed:

- Contemplate the establishment of exposure monitoring programs and preventive behaviour pertaining to zoonoses among workers. Certain labour sectors experience greater exposure to zoonoses, e.g., forestry workers are exposed to tick bites and workers exposed to pigs and poultry are at greater risk of enteric zoonoses. It would, therefore, be possible to actively document certain exposure to zoonoses and the knowledge and preventive behaviour of workers in collaboration with workplaces.
- Explore the possibilities of pooling animal, environmental, and human databases on a single platform: the centralization of the entire array of data would facilitate the detection of emergences and share data between the organizations involved in monitoring and the regional public health branches.
- Explore possibilities for accessing and using data from the provinces and border states. Follow-up to and the analysis of such data can afford early warning of certain emergences. Several existing surveillance systems, especially through collaboration at the federal level, can provide worthwhile data, e.g., FoodNet, and collaboration with federal public health authorities could facilitate access to the data of the other provinces and border states.
- Explore how other innovative data collection and analysis methods could be used to monitor zoonoses, e.g., citizen science projects or possible reliance on genomic technologies.

5. Produce and disseminate information useful for intervention

Ensure the usefulness of the information that monitoring generates and that its dissemination is a significant lever to properly support decision-making and intervention. To this end, several options can be contemplated:

- Evaluate existing monitoring programs: a formal evaluation of monitoring programs would facilitate the measurement of their usefulness and the optimization of financial resources in light of the conclusions. This would also identify which information generated by monitoring guides or facilitates intervention.
- Support the planning of interventions such as information and awareness-raising campaigns by enhancing monitoring activities to include investigations and research devoted to the perceptions, knowledge, and coping behaviours of numerous stakeholders such as individuals, decision-makers, workplaces, and the municipalities.
- Produce forecasts of the geographic distribution of vectors and pathogens based on different global warming scenarios, which would facilitate the anticipation of certain emergences and allow for the planning of interventions accordingly.
- Inform the regional public health branches of procedures for accessing data and the limitations of the monitoring data collected. Such information would respond to the need for access to specific data during investigations or serve to plan regional interventions.
- Broaden efforts to disseminate knowledge stemming from the monitoring data useful for intervention.

5.3 Methodological limitations

The research question that underpins the literature review was fairly broad, which generated a significant number of publications and documents to sort. The number of grey literature documents located on the Google search engine had to be limited and it is possible that certain relevant information was not located. What is more, it may be that certain monitoring activities were not systematically described in the literature consulted since they were covered by unpublished agreements or agreements that produced unpublished data. The synthesis of knowledge nevertheless presents a broad portrait of the monitoring of zoonoses in Québec, but certain particularities may have been overlooked.

As for the interviews with key informants, the selection of the participants influenced the contents of the comments collected. Efforts were made to ensure the diversity of expertise contributing to the monitoring of zoonoses in Québec and the profiles sought were submitted to the consultative committee for validation purposes. The sample of 25 key informants revealed several convergent points but limits the extrapolation of the findings to the perceptions of the key informants from the fields of expertise targeted. Given that collaboration in the realm of the monitoring of zoonoses has changed since the 2011 consultation with the expanding integration of environmental and climatic data, it might be worthwhile to include greater numbers of experts in these fields in a future consultation on the state of the monitoring of zoonoses in Québec.

6 CONCLUSION

This project provides a new overview of the monitoring of tick- and mosquito-transmitted zoonoses and enteric zoonoses in Québec in 2022. It has revealed the progress achieved since 2011 and pinpointed several strong points and opportunities for improvement related to the existing monitoring activities. The project is not intended to provide an exhaustive program evaluation in that it is proposing general avenues for action that will benefit from being prioritized by means of the consultation of the expert panels established for each category of zoonoses, i.e., tick-transmitted and mosquito-transmitted zoonoses and enteric zoonoses. The outcomes can ultimately support decision-making by public health authorities and decision-makers concerning the measures to be adopted to enhance the monitoring of zoonoses already present and at risk of emergence in Québec in the coming years.

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APPENDIX 1 IMPACTS OF CLIMATIC AND ECOLOGICAL CHANGES ON ZOONOSES AND EPIDEMIOLOGICAL STATUS

TICK-TRANSMITTED ZOONOSES

Lyme disease is the most common tick-transmitted zoonosis in Québec. Since the implementation in 2015 of integrated Lyme disease monitoring, an increase in the number of cases acquired in Québec and the geographic distribution of the risk of acquisition has been observed (see Table 9). Lyme disease vector ticks (*Ixodes scapularis*) are present throughout Québec, except in the northernmost regions (Cree Territory of James Bay and Nunavik) and Lyme disease is endemic in several health regions beyond the Estrie and Montérégie regions (25).

Table 9 Number of human Lyme disease cases reported and acquired in Québec, 2012-2021[1]

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Number of cases	16	71	66	112	126	251	223	381	250	650

[1] Source: Ministère de la Santé et des Services sociaux (33).

Other tick-transmitted pathogenic agents are emerging or at risk of emergence in Québec and some are sought among the *Ixodes scapularis* ticks collected in the context of integrated Lyme disease monitoring, including *Anaplasma phagocytophilum*, *Borrelia miyamotoi*, *Babesia microti*, and the Powassan virus. Except for relapsing *Borrelia miyamotoi* fever, the diseases caused by these pathogenic agents are notifiable in Québec. Anaplasmosis accounts for the most cases acquired in Québec, i.e., 61 cases reported from 2019 to 2022 (March 9, 2023, email from N. Ouhoummane, INSPQ[20]).

Climate change is expected to promote the growing abundance of ticks, their propagation toward higher latitudes, and the extension of their seasonal activity (90,91). Furthermore, such changes can create environments favourable to the establishment and spread of other tick species and the diseases that they can transmit, such as *Amblyomma americanun* and ehrlichiosis (90,92).

[20] Sources: Direction de la vigie sanitaire, MSSS. SI-GMI retrieval dated March 2, 2023.

MOSQUITO-TRANSMITTED ZOONOSES

From the standpoint of mosquito-transmitted zoonoses, West Nile virus is a public health concern because of its consequences in terms of morbidity and mortality. The infection is notifiable and has also been subject since 2003 to integrated monitoring, including human, animal, and entomological monitoring (15). Some 70% of the cases reported between 2003 and 2018 displayed neurological damage (15). Marked fluctuations in the number of human WNV infections reported were observed with two spikes in 2012 and 2018 (see Table 10) (15,60). For the period 2012 to 2021, 31 WNV-related deaths were recorded (66). It is anticipated that climatic variations will very likely play a significant role in the life cycle of mosquitoes and hosts and in the amplification in mosquitoes of WNV (15).

Table 10 **Number of reported human WNV cases and deaths in Québec, 2012-2021**[1]

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Cases	134	32	6	45	30	27	201	14	63	14
Deaths	5	1	0	1	2	1	15	0	5	1

[1] Source: Ministère de la Santé et des Services sociaux (66). The number of cases also includes those reported by Héma-Québec, Canadian Blood Services, or infections acquired outside Québec.

Other arborviruses at risk of complications in humans have been notifiable since 2019 (93), including those caused by the California serogroup virus (CSV)[21] which are the most frequently reported after WNV (49), with 16 reported cases in Québec in 2021 (60), and Eastern equine encephalitis virus (EEEV), with respect to which no human case has yet been reported in Québec (94).

Climate change, mainly rising temperatures and fluctuating precipitation, can increase the number of mosquitoes or the transmission of arboviruses, but such increases may differ from site to site since the transmission cycle, reservoirs, and vectors are specific to each arboviral infection (95). Changes in Québec's climate could also promote the establishment of certain mosquitoes, such as *Aedes albopictus*, that are advancing northward in the United States, whose presence in Ontario was detected between 2016 and 2018 (96). The potential establishment of this mosquito poses a health threat for Québec since it is a potential vector for several exotic arboviruses such as Zika, chikungunya, and dengue virus (52,64,67,96).

[21] For additional information on monitoring data pertaining to California serogroup viruses : https://www.msss.gouv.qc.ca/professionnels/zoonoses/surveillance-des-maladies-d-interet-transmises-par-des-moustiques-au-quebec/les-virus-du-serogroupe-californie/.

ENTERIC ZOONOSES

Enteric zoonoses are diseases or infections caused by the ingestion of viruses, bacteria, or parasites that are naturally transmitted between animals and humans (73). They are among the mostly widely reported NDs in Québec. Campylobacteriosis, salmonellosis, and giardiasis display the highest incidence rates (see Table 11). However, enteric zoonoses appear to be underestimated the world since monitoring only detects cases involving individuals who have consulted a physician and been subject to a diagnostic test (73).

Table 11 Average number of reported campylobacteriosis, salmonellosis, and giardiasis cases in Québec, 2000-2017[1]

	Average annual number of reported cases
Campylobacteriosis	Between 2000 and 3000 cases annually
Salmonellosis	1200 cases annually
Giardiasis	Between 800 and 1000 cases annually

[1] Data source: *Portrait des zoonoses entériques au Québec, 2000-2017*. (73)

Certain waterborne or foodborne enteric zoonoses such as campylobacteriosis and salmonellosis could further proliferate as a result of rising temperatures and humidity stemming from climate change. Possible extreme weather events could also generate run-off conducive to water and crop contamination (17).

APPENDIX 2 DATABASE SEARCH ALGORITHMS

OVID PLATFORM

Two databases were searched in the Ovid platform:

1. Medline;
2. Embase.

Table 12 Ovid Medline and Embase queries and results

	Concept 1 – Zoonoses	Medline	Embase
1	(zoonos* or "animal-transmitted infection*" or "animal-transmitted disease*" or "human-animal transmission*" or "animal-human transmission*" or cryptosporidi* or campylobacter* or ((verocytotoxi* or verocyto-toxi* or Shiga-toxi* or Shigatoxi*) and ("Escherichia coli" or "E. coli")) or giardia* or lamblia* or salmonell* or "Yersinia enterocolitica" or listerios* or listeria* or "hepatitis E" or "clostridium botulinum" or botulism or (("waterborne hepatitis" or "waterborne hepatitides" or "water-borne hepatitis" or "water-borne hepatitides" or "enterically-transmitted hepatiti*") and (HEV or "hepatitis E")) or trichinos* or trichinell* or mosquito* or culicidae* or aedes or "anopheles punctipennis" or culex or ochlerotatus* or ochlero-tatus* or "vector insect*" or "insect vector*" or culiseta or "Coquillettidia perturbans" or arbovirus* or arbo-virus* or arboviral or "arthropodborne virus*" or "arthropodborne infection*" or "arthropodborne disease*" or "arthropod-borne virus*" or "arthropod-borne infection*" or "arthropod-borne disease*" or togaviridae or togavirus* or toga-virus* or alphavirus* or alpha-virus* or "alpha virus*" or flavivirus* or flavi-virus* or bunyavirus* or bunya-virus* or bunyaviridae or orthobunyavirus* or ortho-bunyavirus* or bunyamwera or "RNA virus" or "RNA viruses" or "viral encephaliti*" or Dengue or "viral hemorrhagic fever*" or "viral haemorrhagic fever*" or "California encephaliti*" or "California group*" or "California serogroup*" or "Jamestown Canyon" or "La Crosse encephaliti*" or "La Crosse virus*" or "snowshoe hare virus*" or "St. Louis encephaliti*" or "West Nile fever*" or "West Nile virus*" or WNV or "equine encephaliti*" or "equine encephalomyeliti*" or "Yellow fever*" or Zika or "Cache Valley virus*" or Chikungunya or lyme or "borrelia burgdorferi" or "B. burgdorferi" or "ixodes scapularis" or "tick born*" or tickborn* or Powassan or "ixodes cookie" or "amblyomma americanum" or "dermacentor variabilis" or "rhipicephalus sanguineus" or "asian longhorned tick*" or borrelia or "bourbon virus*" or "bush tick*" or "dermacentor anderoni" or "haemaphysalis leporis palustris" or "haemaphysalis longicornis" or "heartland virus*" or "ixodes pacificus" or "amblyomma maculatum" or "relapsing fever*" or "rocky mountain spotted fever*" or "southern tick-associated rash illness" or ((tick or ticks) and (anaplasm* or babesi* or ehrlichi* or rickets* or "Q fever" or "Q fevers" or "query fever" or "query fevers" or "coxiella burnetii" or	233.852	239.878

	tularemia or bartonella)) or "avian influenza" or "avian flu" or "hantavirus pulmonary syndrome*" or "sin nombre virus*" or "sin nombre hantavirus*" or "prospect hill virus*" or "prospect hill hantavirus*").ti,kf.		
2	*Zoonoses/ or exp cryptosporidiosis/ or exp "Shiga-toxigenic Escherichia coli"/ or exp giardiasis/ or exp "giardia lamblia"/ or exp "Yersinia enterocolitica"/ or listeriosis/ or exp "Clostridium botulinum"/ or exp botulism/ or exp "hepatitis E"/ or exp trichinellosis/ or exp trichinellosis/ or exp "listeria monocytogenes"/ or exp culicidae/ or exp aedes/ or exp culex/ or exp ochlerotatus/ or "arthropod vectors"/ or exp "insect vectors"/ or exp "mosquito vectors"/ or exp arboviruses/ or "arbovirus infections"/ or exp Dengue/ or exp "severe Dengue"/ or "encephalitis, arbovirus"/ or exp "encephalitis, California"/ or exp "encephalitis, St. Louis"/ or exp "West Nile fever"/ or exp "West Nile virus"/ or "encephalomyelitis, equine"/ or exp "encephalomyelitis, Eastern equine"/ or exp "yellow fever"/ or exp "Zika virus infection"/ or "RNA virus infections"/ or "Bunyaviridae Infections"/ or "flaviviridae infections"/ or exp "flavivirus infections"/ or "hemorrhagic fevers, viral"/ or "togaviridae infections"/ or "alphavirus infections"/ or exp "chikungunya fever"/ or "encephalitis, viral"/ or "RNA viruses"/ or bunyaviridae/ or Orthobunyavirus/ or exp "Bunyamwera virus"/ or exp "encephalitis virus, California"/ or exp "La Crosse virus"/ or "encephalitis viruses"/ or togaviridae/ or Alphavirus/ or exp "Chikungunya virus"/ or exp "Encephalitis Virus, Eastern Equine"/ or flaviviridae/ or flavivirus/ or exp "dengue virus"/ or exp "yellow fever virus"/ or exp "zika virus"/ or exp "encephalitis viruses, tick-borne"/ or exp "borrelia burgdorferi"/ or exp "tick-borne diseases"/ or exp Ixodidae/ or ticks/ or exp "lyme disease"/ or exp "lyme disease vaccines"/ or exp "influenza in birds"/ or exp "hantavirus pulmonary Syndrome"/ or exp "sin nombre virus"/	241.103	259.804
3	1 or 2	337.618	354.186
Concept 2 – Monitoring		**Medline**	**Embase**
4	exp epidemiology/ or exp "epidemiological monitoring"/ or "public health surveillance"/ or (epidemiolog* or monitoring or surveillance or ((human* or public) adj2 health) or (human* adj2 population)).ti,ab,kf. or epidemiology.fs.	3,168,508	5,898,493
5	3 and 4	96.969	120.130
Concept 3 – Québec		**Medline**	**Embase**
6	(Quebec* or Montreal* or McGill* or Laval* or Sherbrooke* or Nunavik* or Kuujjuaq* or Inukjuak* or Puvirnituq*).ti,ab,kf. or Quebec/	36.556	45.228
7	5 and 6	250	242
8	..l/ 7 yr=2012-3000	139	142

EBSCO PLATFORM

Three databases were searched in EBSCO:

1. Environment Complete;
2. CINAHL Complete;
3. GreenFILE.

The breakdown of the results was consolidated for the three databases.

Table 13 Environment Complete, CINAHL Complete, and Greenfile database queries and results

	Concept 1 – Zoonoses	Results
S1	TI (zoonos* OR "animal-transmitted infection*" OR "animal-transmitted disease*" OR "human-animal transmission*" OR "animal-human transmission*" OR cryptosporidi* OR campylobacter* OR ((verocytotoxi* OR verocyto-toxi* OR Shiga-toxi* OR Shigatoxi*) AND ("Escherichia coli" OR "E. coli")) OR giardia* OR lamblia* OR salmonell* OR "Yersinia enterocolitica" OR listerios* OR listeria* OR "hepatitis E" OR "clostridium botulinum" OR botulism OR (("waterborne hepatitis" OR "waterborne hepatitides" OR "water-borne hepatitis" OR "water-borne hepatitides" OR "enterically-transmitted hepatiti*") AND (HEV OR "hepatitis E")) OR trichinos* OR trichinell* OR mosquito* OR culicidae* OR aedes OR "anopheles punctipennis" OR culex OR ochlerotatus* OR ochlero-tatus* OR "vector insect*" OR "insect vector*" OR culiseta OR "Coquillettidia perturbans" OR arbovirus* OR arbo-virus* OR arboviral OR "arthropodborne virus*" OR "arthropodborne infection*" OR "arthropodborne disease*" OR "arthropod-borne virus*" OR "arthropod-borne infection*" OR "arthropod-borne disease*" OR togaviridae OR togavirus* OR toga-virus* OR alphavirus* OR alpha-virus* OR "alpha virus*" OR flavivirus* OR flavi-virus* OR bunyavirus* OR bunya-virus* OR bunyaviridae OR orthobunyavirus* OR ortho-bunyavirus* OR bunyamwera OR "RNA virus" OR "RNA viruses" OR "viral encephaliti*" OR Dengue OR "viral hemorrhagic fever*" OR "viral haemorrhagic fever*" OR "California encephaliti*" OR "California group*" OR "California serogroup*" OR "Jamestown Canyon" OR "La Crosse encephaliti*" OR "La Crosse virus*" OR "snowshoe hare virus*" OR "St. Louis encephaliti*" OR "West Nile fever*" OR "West Nile virus*" OR WNV OR "equine encephaliti*" OR "equine encephalomyeliti*" OR "Yellow fever*" OR Zika OR "Cache Valley virus*" OR Chikungunya OR lyme OR "borrelia burgdorferi" OR "B. burgdorferi" OR "ixodes scapularis" OR "tick born*" OR tickborn* OR Powassan OR "ixodes cookie" OR "amblyomma americanum" OR "dermacentor variabilis" OR "rhipicephalus sanguineus" OR "asian longhorned tick*" OR borrelia OR "bourbon virus*" OR "bush tick*" OR "dermacentor anderoni" OR "haemaphysalis leporis palustris" OR "haemaphysalis longicornis" OR "heartland virus*" OR "ixodes pacificus" OR "amblyomma maculatum" OR "relapsing fever*" OR "rocky mountain spotted fever*" OR "southern tick-associated rash illness" OR ((tick OR ticks) AND (anaplasm* OR babesi* OR ehrlichi* OR rickets* OR "Q fever" OR "Q fevers" OR "query fever" OR "query fevers" OR "coxiella burnetii" OR tularemia OR bartonella)) OR "avian influenza" OR "avian flu" OR "hantavirus pulmonary syndrome*" OR "sin nombre virus*" OR "sin nombre hantavirus*" OR "prospect hill virus*" OR "prospect hill hantavirus*") OR KW (zoonos* OR "animal-transmitted	86.308

	infection*" OR "animal-transmitted disease*" OR "human-animal transmission*" OR "animal-human transmission*" OR cryptosporidi* OR campylobacter* OR ((verocytotoxi* OR verocyto-toxi* OR Shiga-toxi* OR Shigatoxi*) AND ("Escherichia coli" OR "E. coli")) OR giardia* OR lamblia* OR salmonell* OR "Yersinia enterocolitica" OR listerios* OR listeria* OR "hepatitis E" OR "clostridium botulinum" OR botulism OR (("waterborne hepatitis" OR "waterborne hepatitides" OR "water-borne hepatitis" OR "water-borne hepatitides" OR "enterically-transmitted hepatiti*") AND (HEV OR "hepatitis E")) OR trichinos* OR trichinell* OR mosquito* OR culicidae* OR aedes OR "anopheles punctipennis" OR culex OR ochlerotatus* OR ochlero-tatus* OR "vector insect*" OR "insect vector*" OR culiseta OR "Coquillettidia perturbans" OR arbovirus* OR arbo-virus* OR arboviral OR "arthropodborne virus*" OR "arthropodborne infection*" OR "arthropodborne disease*" OR "arthropod-borne virus*" OR "arthropod-borne infection*" OR "arthropod-borne disease*" OR togaviridae OR togavirus* OR toga-virus* OR alphavirus* OR alpha-virus* OR "alpha virus*" OR flavivirus* OR flavi-virus* OR bunyavirus* OR bunya-virus* OR bunyaviridae OR orthobunyavirus* OR ortho-bunyavirus* OR bunyamwera OR "RNA virus" OR "RNA viruses" OR "viral encephaliti*" OR Dengue OR "viral hemorrhagic fever*" OR "viral haemorrhagic fever*" OR "California encephaliti*" OR "California group*" OR "California serogroup*" OR "Jamestown Canyon" OR "La Crosse encephaliti*" OR "La Crosse virus*" OR "snowshoe hare virus*" OR "St. Louis encephaliti*" OR "West Nile fever*" OR "West Nile virus*" OR WNV OR "equine encephaliti*" OR "equine encephalomyeliti*" OR "Yellow fever*" OR Zika OR "Cache Valley virus*" OR Chikungunya OR lyme OR "borrelia burgdorferi" OR "B. burgdorferi" OR "ixodes scapularis" OR "tick born*" OR tickborn* OR Powassan OR "ixodes cookie" OR "amblyomma americanum" OR "dermacentor variabilis" OR "rhipicephalus sanguineus" OR "asian longhorned tick*" OR borrelia OR "bourbon virus*" OR "bush tick*" OR "dermacentor anderoni" OR "haemaphysalis leporis palustris" OR "haemaphysalis longicornis" OR "heartland virus*" OR "ixodes pacificus" OR "amblyomma maculatum" OR "relapsing fever*" OR "rocky mountain spotted fever*" OR "southern tick-associated rash illness" OR ((tick OR ticks) AND (anaplasm* OR babesi* OR ehrlichi* OR rickets* OR "Q fever" OR "Q fevers" OR "query fever" OR "query fevers" OR "coxiella burnetii" OR tularemia OR bartonella)) OR "avian influenza" OR "avian flu" OR "hantavirus pulmonary syndrome*" OR "sin nombre virus*" OR "sin nombre hantavirus*" OR "prospect hill virus*" OR "prospect hill hantavirus*") OR SU (zoonos* OR "animal-transmitted infection*" OR "animal-transmitted disease*" OR "human-animal transmission*" OR "animal-human transmission*" OR cryptosporidi* OR campylobacter* OR ((verocytotoxi* OR verocyto-toxi* OR Shiga-toxi* OR Shigatoxi*) AND ("Escherichia coli" OR "E. coli")) OR giardia* OR lamblia* OR salmonell* OR "Yersinia enterocolitica" OR listerios* OR listeria* OR "hepatitis E" OR "clostridium botulinum" OR botulism OR (("waterborne hepatitis" OR "waterborne hepatitides" OR "water-borne hepatitis" OR "water-borne hepatitides" OR "enterically-transmitted hepatiti*") AND (HEV OR "hepatitis E")) OR trichinos* OR trichinell* OR mosquito* OR culicidae* OR aedes OR "anopheles punctipennis" OR culex OR ochlerotatus* OR ochlero-tatus* OR "vector insect*" OR "insect vector*" OR culiseta OR "Coquillettidia perturbans" OR arbovirus* OR arbo-virus* OR arboviral OR "arthropodborne virus*" OR "arthropodborne infection*" OR "arthropodborne disease*" OR "arthropod-borne virus*" OR "arthropod-borne	

	infection*" OR "arthropod-borne disease*" OR togaviridae OR togavirus* OR toga-virus* OR alphavirus* OR alpha-virus* OR "alpha virus*" OR flavivirus* OR flavi-virus* OR bunyavirus* OR bunya-virus* OR bunyaviridae OR orthobunyavirus* OR ortho-bunyavirus* OR bunyamwera OR "RNA virus" OR "RNA viruses" OR "viral encephaliti*" OR Dengue OR "viral hemorrhagic fever*" OR "viral haemorrhagic fever*" OR "California encephaliti*" OR "California group*" OR "California serogroup*" OR "Jamestown Canyon" OR "La Crosse encephaliti*" OR "La Crosse virus*" OR "snowshoe hare virus*" OR "St. Louis encephaliti*" OR "West Nile fever*" OR "West Nile virus*" OR WNV OR "equine encephaliti*" OR "equine encephalomyeliti*" OR "Yellow fever*" OR Zika OR "Cache Valley virus*" OR Chikungunya OR lyme OR "borrelia burgdorferi" OR "B. burgdorferi" OR "ixodes scapularis" OR "tick born*" OR tickborn* OR Powassan OR "ixodes cookie" OR "amblyomma americanum" OR "dermacentor variabilis" OR "rhipicephalus sanguineus" OR "asian longhorned tick*" OR borrelia OR "bourbon virus*" OR "bush tick*" OR "dermacentor anderoni" OR "haemaphysalis leporis palustris" OR "haemaphysalis longicornis" OR "heartland virus*" OR "ixodes pacificus" OR "amblyomma maculatum" OR "relapsing fever*" OR "rocky mountain spotted fever*" OR "southern tick-associated rash illness" OR ((tick OR ticks) AND (anaplasm* OR babesi* OR ehrlichi* OR rickets* OR "Q fever" OR "Q fevers" OR "query fever" OR "query fevers" OR "coxiella burnetii" OR tularemia OR bartonella)) OR "avian influenza" OR "avian flu" OR "hantavirus pulmonary syndrome*" OR "sin nombre virus*" OR "sin nombre hantavirus*" OR "prospect hill virus*" OR "prospect hill hantavirus*")	
Concept 2 – Monitoring		**Results**
S2	TI (epidemiolog* OR monitoring OR surveillance OR ((human* OR public) N2 health) OR (human* N2 population)) OR AB (epidemiolog* OR monitoring OR surveillance OR ((human* OR public) N2 health) OR (human* N2 population)) OR KW (epidemiolog* OR monitoring OR surveillance OR ((human* OR public) N2 health) OR (human* N2 population)) OR SU (epidemiolog* OR monitoring OR surveillance OR ((human* OR public) N2 health) OR (human* N2 population))	1,272,705
Concept 3 – Québec		**Results**
S3	TI (Quebec* OR Montreal* OR McGill* OR Laval* OR Sherbrooke* OR Nunavik* OR Kuujjuaq* OR Inukjuak* OR Puvirnituq*) OR AB (Quebec* OR Montreal* OR McGill* OR Laval* OR Sherbrooke* OR Nunavik* OR Kuujjuaq* OR Inukjuak* OR Puvirnituq*) OR KW (Quebec* OR Montreal* OR McGill* OR Laval* OR Sherbrooke* OR Nunavik* OR Kuujjuaq* OR Inukjuak* OR Puvirnituq*) OR SU (Quebec* OR Montreal* OR McGill* OR Laval* OR Sherbrooke* OR Nunavik* OR Kuujjuaq* OR Inukjuak* OR Puvirnituq*)	33.252
S4	S1 AND S2 AND S3	109
S5	S4 AND (DT 2012-3000)	79

APPENDIX 3 PROFILE OF THE KEY INFORMANTS

Table 14 Initial training of the key informants (n=25)

Initial training	N	Details
Medicine	11	
Veterinary medicine	6	
Other	8	University studies in biology, nursing, environmental health, and community health
Specializations	Epidemiology, entomology, microbiology-infectiology, occupational health, virology-parasitology, molecular biology, ecology	

Table 15 Health sectors and workplaces of the key informants (n=25)

Health sectors	N	Workplaces
Human health	16	MSSS, DSPu/CIUSSS*, Héma-Québec, INSPQ, LSPQ
Animal health	6	FMV de l'UdeM, MAPAQ, FMV laboratory (parasitology), MAPAQ laboratory
Wildlife health and vectors	3	MFFP, FMV (CQSAS), consultant
*Details	Outaouais, Estrie, Laval, Montréal, Montérégie, and Laurentides regions	

APPENDIX 4 NAMES AND AFFILIATIONS OF THE CONSULTATIVE COMMITTEE MEMBERS

First name and last name	Professional title and main affiliation(s)
Magalie Canuel	Scientific Advisor Direction de la santé environnementale et de la toxicologie, INSPQ
Alex Carignan	Microbiologist-Infectiologist CIUSSS de l'Estrie-CHUS
Geoffroy Denis	Medical Officer DSPu de Montréal, CIUSSS du Centre-Sud-de-l'Île-de-Montréal Direction générale de la santé publique, MSSS
Colette Gaulin	Medical Officer Direction de la vigie sanitaire, MSSS
Marie-Claude Lacombe	Medical Officer DSPu des Laurentides, CISSS des Laurentides
Louise Lambert	Medical Officer Direction de santé publique de la Montérégie, CISSS Montérégie-Centre Direction des risques biologiques, INSPQ
Ariane Massé	Biologist Direction de l'expertise sur la faune terrestre, l'herpétofaune et l'avifaune, Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs
François Milord	Medical Officer DSPu de la Montérégie, CISSS Montérégie-Centre
Nicholas Ogden	Senior Research Scientist and Director Public Health Risk Sciences Division, PHAC
Isabelle Picard	Veterinarian Direction de la santé animale, MAPAQ
Pierre A. Pilon*	Medical Officer DSPu de Montréal, CIUSSS du Centre-Sud-de-l'Île-de-Montréal * Contributed to the initial stages of the project but was unable to participate in the consensus-building activity.
André Ravel	Full Professor Épidémiologie et santé publique vétérinaire, Faculté de médecine vétérinaire de l'Université de Montréal

APPENDIX 5 INTERVIEW CANVAS

WORD OF WELCOME TO THE KEY INFORMANTS
Hello, Thank you for agreeing to participate in this consultation section in the context of our project devoted to the monitoring of zoonoses in Québec. We are seeking your participation as a key informant because of your expertise in the field of XXXX. The interview will last between 30 and 45 minutes and seek to: • identify the strong points and opportunities for improvement concerning structures, programs, and zoonosis epidemiological monitoring activities in Québec; • identify the avenues for action and knowledge needs to optimize the monitoring of zoonoses with a view to guiding the implementation of prevention initiatives. Remember that your perceptions and reflections are valuable in the context of this consultation. Have you read the briefing document that was sent to you? Do you have any questions on its contents before the interview begins? With your consent, today's session will be recorded. This recording will remain confidential and will not be shared in any form with anyone. Moreover, your name will not be cited in the report.
PERSONAL INFORMATION
We would first like to obtain information on your work. The data will be presented in a form that preserves your anonymity.
1. How long have you held the position of XXXX in (name the respondent's place of employment)? (If in the position for less than one year) What position did you hold previously?
2. What initial training did you receive?
3. Can you tell me about your experience in the realm of the monitoring of zoonoses and zoonoses (for those who are not engaged in monitoring)? • Number of years of experience • Type of experience in the realm of monitoring • Zoonoses encountered • The main objective of your activities related to zoonoses • Key collaborators, where applicable

INTERVIEW CANVAS (CONTINUED)

PERCEPTION OF THE MONITORING OF ZOONOSES
We are going to discuss the strong points and opportunities for improvement of the monitoring of zoonoses. Improvements are understood in the broad sense to better detect and prevent cases of zoonoses. We will examine the factors that facilitate or limit the monitoring of zoonoses.
4. Based on your experience, what, in your view, are the strong points and opportunities for improvement with respect to the monitoring of zoonoses in Québec? *Make note to summarize them in question 6 If the answers are too vague or if the respondent has not read to checklist: Are there points concerning, more specifically: • data input (data collection, integration, and validation, including the diagnostic capacity of laboratories)? • the production of information (data analysis and interpretation)? • the dissemination of information adapted to different users? • support for decision-making (planning, inter-agency or inter-organization collaboration, and the implementation of province-wide intervention)?
You have just raised several opportunities for improvement (quote what the respondent has identified). I would now like to turn to what you deem to take priority.
5. In your opinion, what three priority actions should be implemented to enhance the monitoring of zoonoses in Québec in the coming decade?
6. What knowledge needs do you believe need to be satisfied in connection with these strong points and opportunities for improvement? *Make note to summarize them in question 7 Examples: Develop knowledge on the ecology of pathogenic agents or hosts Grasp the impact of the management of the environment on the transmission of zoonoses Develop detection systems that integrate human and animal monitoring data, e.g., entomological surveillance and pathogen detection Develop new monitoring systems Develop an early episode alert system Develop diagnostic tools or new tests, e.g., genomic typing Develop new province-wide initiatives Focus on the user education and information through targeted programs Any other relevant point

INTERVIEW CANVAS (CONTINUED)

PERCEPTION OF THE MONITORING OF ZOONOSES (CONTINUED)
You have just indicated several knowledge needs to be satisfied (quote what the respondent has identified). I would like to know what you deem to take priority in this respect.
7. In your opinion, what three priority actions should be implemented to respond to the knowledge needs to be established to enhance the monitoring of zoonoses in Québec in the coming decade?
MATCHING WITH CLIMATIC OR ECOLOGICAL CHANGES
You have raised strong points and opportunities for improvement in the realm of the monitoring of zoonoses and knowledge needs related to the monitoring of zoonoses. We will now discuss the impact of climatic and ecological changes on the monitoring of zoonoses.
8. Do you believe that the existing monitoring of zoonoses is properly adapted to the anticipated changes stemming from climatic or ecological changes? You can focus your response on the zoonoses that you know best. → If so, can you give me examples and explain why? → If not, are the enhancements to be made similar to what was discussed earlier?* What should be improved in the realm of the monitoring of zoonoses in light of climatic and ecological changes? *Return to the points raised in question 4, if necessary.
9. Do you believe that the knowledge being produced is properly adapted to the anticipated changes stemming from climatic or ecological changes? You can focus your response on the zoonoses that you know best. → If so, can you give me examples and explain why? → If not, are the knowledge needs similar to what was discussed earlier, i.e., repeat the key points raised in question 8? What knowledge needs stem from climate change?
The interview is almost over. I would like to ask a final question to conclude our discussion.
10. Is there a significant aspect related to zoonoses that you would like to add that we did not cover during the interview? If so, which one?
Thank you for participating in our project.

APPENDIX 6 BRIEFING DOCUMENT

Monitoring Zoonotic Diseases in Québec: Overview and Avenues for Action

Briefing paper for the key informants

Objectives of the interview:

- identify the strong points and opportunities for improvement of the structures, programs, and zoonosis epidemiological monitoring activities in Québec;
- identify the avenues for action and knowledge needs to optimize the monitoring of zoonoses with a view to guiding the implementation of preventive intervention.

Questions broached

- Based on your experience, what, in your view, are the strong points and opportunities for improvement with respect to the monitoring of zoonoses in Québec?
- Do you believe that the existing monitoring of zoonoses is properly adapted to the anticipated changes stemming from climate change? Why?
- What knowledge needs do you believe need to be developed in connection with these strong points and opportunities for improvement?

Definitions

Monitoring of zoonoses

- According to Thacker *et al.*[22] (1996), monitoring is an "ongoing process to assess the health status of a population and its determinants by means of the collection, analysis, and interpretation of health-related data and its determinants in a population."
- The monitoring of zoonoses in this project is understood in the broad sense and encompasses the monitoring of human cases, pathogens, hosts, vectors, and water or food that can contain the same pathogens. The ultimate aim of monitoring is to protect the health of the population from health-related threats linked to zoonoses.
- The *Public Health Act* (2001, c. 60, s. 33, (20)) stipulates that "Ongoing surveillance of the health status of the population and of health determinants shall be carried out so as to: (1) obtain an overall picture of the health status of the population; (2) monitor trends and temporal and spatial variations; (3) detect emerging problems; (4) identify major problems; (5) develop prospective scenarios of the health status of the population; (6) monitor the development within the population of certain specific health problems and of their determinants."

[22] Thacker, S. *et al.*, (1996) Surveillance in environmental public health: issues, systems, and sources. Am. J. public Health, 86(5), 633-638.

Climate change

- According to the IPCC[23] (2013), climate change is a detectable change in the climate, e.g., by means of statistical tests, through changes in the average and/or variability of its properties, which persist over a long period, usually for decades or more.
- Climate change can alter temperature and precipitation and, consequently, affect the spread of zoonotic pathogens or the reproduction rate and geographic distribution of their vectors. What is more, rising temperatures can potentially affect human activity and thus prolong periods of potential exposure to the vectors or environments contaminated by zoonotic pathogens. [24,25]

Knowledge needs

- The expression "knowledge needs" in the context of this project encompasses the entire array of information, training, and knowledge needs.
- It refers to the entire array of knowledge that is useful and relevant from the standpoint of public health initiatives,[26], i.e., data on the health status and well-being of the population, administrative data, management knowledge, intervention-related knowledge, and evaluation and research outcomes.

[23] IPCC, 2013: Glossary [Planton, S. (coord.)]. In: Changements climatiques 2013: Les éléments scientifiques. Contribution du Groupe de travail I au cinquième Rapport d'évaluation du Groupe d'experts intergouvernemental sur l'évolution du climat.

[24] Belanger D, *et al*. Santé et changements climatiques : Évaluation des vulnérabilités et de la capacité d'adaptation au Canada. Ottawa (ON): Health Canada; 2008.

[25] Germain G, *et al*. Observatoire multipartite québécois sur les zoonoses et l'adaptation aux changements climatiques. Relevé des maladies transmissibles au Canada 2019;45(5):159–64.

[26] Direction générale de la santé publique (2007). Cadre d'orientation pour le développement et l'évolution de la fonction de surveillance au Québec. Québec, MSSS: 51 pages.

APPENDIX 7 COMPARISON OF THE AVENUES FOR ACTION

Table 16 Comparison of the main avenues for action proposed in 2011 and the monitoring of zoonoses under way in Québec in 2022

Main avenues for action in 2011	The situation in 2022
Anticipate the emergence of zoonoses	
• Implement a Lyme disease monitoring system	• An integrated Lyme disease monitoring system was established in 2015
• Maintain the monitoring of the emergence of zoonotic diseases in wildlife	• Since 2005, the *Stratégie québécoise sur la santé des animaux sauvages* has maintained collaboration and consultation between the MAPAQ, the MFFP, the MSSS, and the FMV de l'UdeM (implemented by the CQSAS)
• Establish monitoring of mosquitoes and their pathogenic agents	• Entomological surveillance was established from 2012 to 2021, then suspended for the summer of 2022
• Provide the necessary expertise on zoonoses to professionals from the regional public health branches and human health clinicians to quickly detect abnormal events, e.g., a centralized Web-based information source	• Several information dissemination and knowledge transfer initiatives have been undertaken since 2012, e.g., Lyme disease mapping (INSPQ), the *Guide d'identification des tiques* (LSPQ), and Flash Vigie bulletins (MSSS) • Not all information is centralized on a single channel: some information is found at the INSPQ, other information at the MSSS or the INESSS, and other information is relayed by the regional public health branches
• Heighten awareness among physicians and veterinarians of zoonotic diseases that are significant in the realm of human medicine and their role in the detection and reporting of zoonotic diseases (interdisciplinary approach)	• Not all the activities that have taken place since 2011 have been inventoried • This need stems once again from the comments reported in the interviews with key informants in 2022 (in the knowledge needs)
Consolidate monitoring	
• Foster collaboration between government human health, farm animal health, and wildlife agencies and research institutions to facilitate the implementation of long-term partnerships and generic tools to respond rapidly to the emergence of a disease	• Collaboration is ongoing through deliberations, agreements, and existing strategies • Limited funding over time: its sustainability is not assured • Generic tools that facilitate a rapid response to the emergence of a disease: no specific tool has been developed to this end, but networks rapidly disseminate information

Table 16 Comparison of the main avenues for action proposed in 2011 and the monitoring of zoonoses under way in Québec in 2022 (continued)

Main avenues for action in 2011	The situation in 2022
• Examine in greater depth collaboration and networking needs between the human health disciplines and institutions mentioned by the provincial respondents. Such needs could necessitate the establishment of a more robust organizational structure for the monitoring of non-enteric zoonoses in the realm of human health	• Since 2015, the Comité scientifique sur les zoonoses et l'adaptation aux changements climatiques at the INSPQ has coordinated the deliberations of panels of experts focusing on tick- and mosquito-transmitted diseases and enteric zoonoses
• Prioritize enteric and non-enteric zoonoses bearing in mind, by way of an example, climate-change-related and ecological risks in order to improve diagnostic tools in the realm of human health. This would consolidate and unite efforts in a context of limited funding	• The Observatoire multipartite québécois sur les zoonoses et l'adaptation aux changements climatiques carried out two prioritization exercises in 2015 and in 2017
• Enhance the nature of data analysis. Promote reports that present province-wide spatial coverage, ongoing temporal coverage, and a joint analysis of data of different origins, i.e., human health, animal health, and the environment	• Integrated Lyme disease and WNV monitoring is ongoing, but the environmental components have yet to be developed
• Better document the importance of zoonoses linked to pets and new pets, e.g., new exotic species and imports from outside Canada	• Depending on the results collected, there is no action to this effect for the zoonoses considered in this project

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