Prioritization tools for diseases and interventions targeting populations in Africa and Canada vulnerable to water-related health issues

Research report submitted to Ouranos

June 2016

Under the direction of
Pascal Michel, Université de Montréal

Table of contents

List of Figures viii

List of Tables viii

1. Introduction 9

2. Context / objectives 9

3. Theoretical framework / summary of the literature 11

Climate Sensitive Infectious Diseases (CSIDs) 11
Adaptation and adaptive capacity 12
Multi-criteria decision aid (MCDA) and public health 14

4. Methodology / data 15

Disease prioritization 15
Multi-criteria decision analysis 15
Comparison between study regions 17
Intervention prioritization 18
Multi-criteria decision analysis 19

5. Results 20

Disease prioritization 20
Criteria 21
Pilot prioritization 25
Intervention Prioritization 26
West Nile virus in Quebec 26
Malaria in Burkina Faso 33
Lyme disease in Manitoba 37

6. Analysis and discussion 42

Disease prioritization 42
Intervention prioritization 44
West Nile virus in Quebec 44
Malaria in Burkina Faso 47
Lyme disease in Manitoba 47

7. Conclusion and recommendations 52

8. References 55

9. Appendices 60

Appendix 1 – West Nile virus risk transmission scenarios 61
Appendix 2 – Quebec stakeholder weights for scenarios 63
Appendix 3 – West Nile virus intervention profiles 66
Appendix 4 – Criteria included in the Manitoba Lyme model 69
Appendix 4 - Modifications made to Quebec Lyme disease evaluations for the Manitoban context 72
Appendix 5 - Multi-Stakeholder Decision Aid for Improved Prioritization of the Public Health Impact of Climate Sensitive Infectious Diseases* 75

List of Figures

FIGURE 1. CONCEPTUAL OVERVIEW OF RELATIONSHIP BETWEEN CLIMATE AND INFECTIOUS DISEASES [80].....13
FIGURE 2. STEPS IN A MULTI-CRITERIA DECISION ANALYSIS (MCDA) PROCESS (SEE (63)).....16
FIGURE 3. AVERAGE WEIGHTING OF DISEASE DECISION CRITERIA CATEGORIES BY REGIONS.....24
FIGURE 4. GAIA DECISION MAP FOR QC REGIONAL-LEVEL MODEL.....29
FIGURE 5. INTERVENTION PROFILES FOR SIX INDIVIDUAL-LEVEL PROTECTION INTERVENTIONS. 31
FIGURE 6. REGIONAL-LEVEL MANAGEMENT INTERVENTION RANKING FOR BF.....35
FIGURE 7: GAIA STAKEHOLDER MAP FOR ALL ACTIONS WEIGHTED FOR LOW TRANSMISSION SCENARIO 49
FIGURE 8: INDIVIDUAL STAKEHOLDER RANKINGS FOR LOW TRANSMISSION SCENARIO 49
FIGURE 9: GAIA STAKEHOLDER MAP FOR ALL ACTIONS WEIGHTED FOR HIGH TRANSMISSION SCENARIO.....51
FIGURE 10. INDIVIDUAL STAKEHOLDER RANKINGS FOR HIGH TRANSMISSION SCENARIO.....51

List of Tables

TABLE 1 EXAMPLES OF CLIMATE SENSITIVE MECHANISMS.....12
TABLE 2. HYPOTHETICAL LYME DISEASE TRANSMISSION SCENARIOS FOR CRITERIA WEIGHTING.....20
TABLE 3. CRITERIA FOR THE PRIORITIZATION OF CLIMATE SENSITIVE INFECTIOUS DISEASES 21
TABLE 4. QUEBEC STAKEHOLDER WEIGHTS FOR ALL CRITERIA.....22
TABLE 5. BURKINA FASO STAKEHOLDER WEIGHTS FOR ALL CRITERIA 23
TABLE 6. PILOT CLIMATE SENSITIVE INFECTIOUS DISEASE CRITERIA EVALUATIONS FOR QUEBEC 25
TABLE 7. PILOT CLIMATE SENSITIVE INFECTIOUS DISEASE CRITERIA EVALUATIONS FOR BURKINA FASO 26
TABLE 8. INTERVENTIONS FOR THE MANAGEMENT OF WNV IN QC 26
TABLE 9. CRITERIA FOR THE MANAGEMENT OF WEST NILE VIRUS IN QUEBEC.....27
TABLE 10. CRITERIA WEIGHTING BY QC STAKEHOLDERS.....28
TABLE 11. RANKING OF THE INDIVIDUAL-LEVEL PROTECTION INTERVENTIONS FOR QC. 30
TABLE 12. RANKING OF THE REGIONAL-LEVEL MANAGEMENT INTERVENTIONS FOR QC. 32
TABLE 13. RANKING OF COMBINED INDIVIDUAL-LEVEL AND REGIONAL-LEVEL MANAGEMENT INTERVENTIONS FOR QC.....32
TABLE 14. INTERVENTIONS FOR THE MANAGEMENT OF MALARIA IN BF. 34
TABLE 15. CRITERIA FOR THE MANAGEMENT OF MALARIA IN BURKINA FASO. 35
TABLE 16. CRITERIA WEIGHTS BY STAKEHOLDERS 36
TABLE 17. RANKING OF THE REGIONAL-LEVEL MANAGEMENT INTERVENTIONS FOR BF.....36
TABLE 19. LOW INCIDENCE SCENARIO WEIGHTINGS BY STAKEHOLDER (S1-S9) FOR ALL CRITERIA. 38
TABLE 20. HIGH INCIDENCE SCENARIO WEIGHTINGS BY STAKEHOLDER (S1-S9) FOR ALL CRITERIA. 38
TABLE 21. INTERVENTIONS INCLUDED IN THE MODELS.....40
TABLE 23. RANK AND SCORE OF ALL POTENTIAL ACTIONS ACCORDING TO ALL STAKEHOLDERS FOR THE LOW TRANSMISSION SCENARIO 48
TABLE 24. RANK AND SCORE OF ALL POTENTIAL ACTIONS ACCORDING TO ALL STAKEHOLDERS FOR THE HIGH INCIDENCE TRANSMISSION SCENARIO 50

1. Introduction

In the context of climate change adaptation, it is critical to identify and characterize vulnerabilities to climate change, and generate appropriate data for integrated adaptation measures. Towards this end, structured and transparent, participatory decision aid tools can serve as a unifying process to bring together a diverse array of stakeholders and types of data in order to share and discuss issues and considerations of concern when facing complex decision problems such as those posed by climate change and particularly those related to vector-borne and zoonotic diseases which lie at the interface between humans, animals and the environment.

This project set out to develop a customized prioritization tool using a multicriteria/multi-actor decision analysis (MCDA) approach to prioritize vulnerability and adaptation actions to climate change focused on the needs of end users. This tool for prioritizing and integrating a wide range of available information, including both scientific evidence and stakeholder informed discussions was assessed in the context of two contrasting study regions, one low-income and one high-income (Burkina Faso and Quebec). The approach used to prioritize both diseases and interventions pertaining to climate sensitive infectious diseases can be adapted and applied to other health issues in other regions, in order to improve planning for public health hazards related to climate change in other regions and contexts. Ultimately, adaptation measures that are grounded in the realities of the field, and therefore more easily applicable by local authorities and communities, emerge from these processes.

2. Context / objectives

Health is dependent on many determinants ranging from our genetic and physical environment in which we live to the social environments in which we interact, affecting our ability to adapt and cope with challenges (1). Climate influences many of these determinants through direct effects on the physical environment or indirect effects such as economic and psychological impacts resulting from natural disasters that can disrupt the social environment of an individual and their resilience (2).An important aspect of our changing climate relates to the changing dynamics of water resources. In recent decades, it is estimated that climate change has contributed to desertification and increasing water shortages in parts of Africa (3) and increased risk of flooding in other regions. In Canada, it is expected that climate change will increase the frequency of heavy rainfall and the risk of flooding that can damage infrastructures and ecosystems (1). Climate change not only affects human health through direct effects (e.g. extreme heat, floods, etc ...), but can also affect health through effects on supporting systems (e.g. animal and ecological health, biodiversity, economic activities) all of which should be considered in adaptation planning. Changes to these supporting systems, coupled with climate change and other socio-environmental changes have been linked to the increased emergence and re-emergence of infectious diseases, including vector-borne diseases (4,5). Heavy rains, flooding and high temperatures contribute to increased breeding sites for disease vectors such as mosquitoes and have been linked to outbreaks of Rift Valley fever in parts Africa (6) and outbreaks of West Nile virus and western equine encephalitis in parts of North America (7). Changing water resources dynamics due to ongoing climate change could alter the risk of vector and water-borne diseases in different regions of the world with the most significant impacts affecting the most vulnerable populations in these areas. In this context, it is essential not only to be able to identify areas at risk, but also to identify and mobilize

vulnerable populations in these areas and propose sound mitigation strategies, appropriate and acceptable for all.

This project focused on adapting to climate change related issues and included end-users, researchers and decision makers committed to active participation in these studies in countries of study by the project. To this end, we set out to identify the socioeconomic and environmental factors (criteria) contributing to the vulnerability of people to the risks of vector-borne diseases associated with the changing dynamics of water resources (heavy rains, floods and droughts) by adopting a multi-criteria decision aid approach (MCDA). MCDA is a decision support tool that has been commonly used in various sectors such as environmental management, engineering and management allowing for the organization and ranking of actions or alternatives in accordance with their performance measured via quantitative and qualitative criteria (8). A comparative analysis (specificity, contrasts, similarities) of climate sensitive infectious diseases and interventions was undertaken in two regions: southern Quebec (Canada) and Burkina Faso (West Africa), applying MCDA as a rigorous and transparent tool for the realization of the management of health issues, identification of concrete indicators of vulnerability of the population, as well as a practical tool for the active participation of stakeholders and knowledge transfer. This approach contributes to the thoughtful identification of climate sensitive infectious diseases of concern in accordance with local priorities and contributes to integrate adaptive planning to manage and control vector-borne diseases in accordance with locally held values.

In this context, three main objectives were identified:

1. To examine, assemble and discuss existing scientific information (knowledge synthesis) on climate sensitive infectious diseases and health impacts related to vector-borne and zoonotic diseases under changing water dynamics in Quebec and in Burkina Faso, comparing and contrasting socio-economic and environmental inequalities that contribute to these health impacts.
2. To describe and compare, by cross-sectional study in two study areas (Quebec and Burkina Faso), perceived concerns and capacities of the public to adapt and cope with changes to the risks posed by vector-borne and zoonotic diseases in a context of climate change.
3. To assess and validate a specific set of indicators of vulnerability to diseases studied through the development of a multi-criteria / multi-actor process (MCDA tool and process). This will include a participatory process with local stakeholders to evaluate the different viewpoints and offer seamless integration of these views. While targeting a specific theme (Vulnerability changing water dynamics) MCDA will be applied as a process that can be generalized and transferred to different health goals or other areas.

A fourth objective had originally been planned pertaining to spatial models but had to be dropped due to time constraints following field work difficulties resulting from political instability in the originally planned study region Niamey (Niger). As a result of this change, the original GIS database phase of the project was abandoned (T3.1.9) as was mentioned in the first progress report sent in February 2014. In conjunction with the abandon of this phase of the project, the integration in the SUPREME system was no longer relevant given this adjustment. Modifications were made to move the planned field work to a region in a neighbouring country Ouagadougou (Burkina Faso) and a validation model in Manitoba (Canada) was also added to the project as a fall back in case further difficulties were encountered in carrying out the field work. The validation module carried out in Manitoba is also included in this report.

3. Theoretical framework / summary of the literature

Climate change is one process amidst a larger context of human induced social-environmental changes that are affecting ecosystem dynamics and consequently having an impact on health including climate sensitive infectious disease (CSIDs). Various determinants of health such as the environmental characteristics of the location where individuals live, local physical infrastructures, social and institutional contexts and demographic factors affect an individual's exposure and underlying sensitivity to CSIDs as well as their ability to cope or respond (adaptive capacity) to CSIDs. As part of the first phase of this research project, factors were identified to help prioritize CSIDs in two study regions of interest: Quebec and Burkina Faso. In the second phase, an endemic vector-borne CSID was selected in each of the study regions and factors important to consider in managing these diseases were identified in the context of each of the study regions.

Climate Sensitive Infectious Diseases (CSIDs)

Climate sensitive infectious diseases (CSIDs) are communicable diseases, usually vector-borne, waterborne, foodborne, or airborne diseases, with a component of their transmission that is sensitive to changes in temperature or precipitation and related environmental variables (e.g. humidity, length of growing season). The transmission of many infectious diseases is sensitive to weather conditions, particularly those with life cycles outside of the human body (9). These diseases encompass those diseases likely to 1) emerge, 2) re-emerge or 3) change their geographical or temporal distribution as a result of ongoing changes to climate (6). Some of the better known examples of vector-borne CSIDs include Malaria, known to be endemic in Burkina Faso (10), and WNv, that has been circulating in Quebec since 2002 (11), both of which are mosquito-borne diseases, where the mosquito vector is the climate sensitive component of transmission. Other CSIDs include a number of enteric waterborne and foodborne infections such as *Salmonella*, pathogenic *E. coli* and *Campylobacter*, which are pathogens that have been shown to have increased growth rates as temperatures rise (12). A short list of CSIDs and their climate sensitive components is shown in table 1.

From a simplified perspective, changes in weather and climate result in changing incidence of CSIDs due to changes in the rate of proliferation, survival and transmission of pathogens and their vectors. The seasonal and spatial patterns of these agents may also change (6). Temperature and precipitation changes affect water cycle dynamics and in turn can have implications for ecosystems, microbial and parasitic evolution. For VBDs, changes to the water cycle or water cycle dynamics can affect the availability of breeding places for vector species. Heavy rainfall, flooding and drought conditions can all increase breeding space for vector species such as mosquitoes (via pools of water left behind following flood and/or drought events) and have been linked to VBD outbreak events such as Rift valley fever in parts of Africa (7). Drought has also been linked to amplification of Saint Louis encephalitis virus in Florida as dwindling water sources may increase the likelihood of multispecies contact at available water sources (13). Changes to temperature can affect the reproduction rate, survival rate and rate of contact of vectors with host species as well as the replication and survival of pathogens within vector species. Changes in incidence of Malaria have been observed in south America in correlation with the El Nino Southern Oscillation (ENSO) (14), and outbreaks of WNv and western equine encephalitis have been linked with warmer than usual temperatures in parts of North America (15). Heavy rainfall, flooding and drought conditions can increase the risk of contamination of drinking water sources as a result of runoff following extreme precipitation events as occurred with the E. coli O157 outbreak in Walkerton, Ontario (16). Drought and runoff can also increase the pathogen concentration in drinking water supplies as has been observed in parts of rural Quebec (17). Similarly, changes in temperature also affect the reproduction and survival rate of waterborne pathogens.

From a public health perspective, CSIDs are complex diseases to study and to plan for because they arise at the interface of multiple interconnected systems and scales – human, environmental, animal - and our technical and societal adaptations to these changes are challenging (18). Socio-economic factors and resulting behavioural changes as well as other forces have been shown to play an important role in the emergence of CSIDs as observed recently in California with increases in WNv following foreclosures of homes and resulting abandoned swimming pools (19). Warmer weather has been identified as a likely motivator for people to spend more time in the sun and as such is likely to increase the risk of skin cancers (20). Warmer weather and the likely resulting behavioural change of people spending more time outdoors may also increase the chances of contact with mosquitoes thereby increasing the risk of VBD transmission. Additionally, driving forces such as global ecosystem change, the existence of suitable climate, the geopolitical stability of a region, the economic stability and related nutritional status and general health of a population, state of the underlying health infrastructure, the immunity of the local population, the existence of suitable vectors and reservoir hosts, changes in human behavior and other factors are crucial components that need to be taken into account when planning public health strategies (see Fig. 1)(6,21).

Table 1 Examples of climate sensitive mechanisms

Climate variables	Effect of climate change and Climate sensitive components	Disease examples
Heavy rainfall, flooding and warm temperatures	Increase in breeding space for vector species such as mosquitoes (via pools of water left behind following flood events) Increased temperatures also accelerate vector reproduction and pathogen proliferation within the vector	Malaria, Rift valley fever, WNv
Heavy rainfall, flooding and warm temperatures	Waterborne pathogen proliferation and contamination via runoff Warmer temperatures accelerate pathogen proliferation	*E. Coli* O157, Cryptosporidiosis
Drought conditions and warm temperatures	Increased breeding space for vector species such as mosquitoes (via pools of water left behind following drought events) Reduced number of water sources provides an opportunity for increased encounters of various species at available water sources Increased temperatures also accelerate vector reproduction and pathogen proliferation within the vector	Saint Louis encephalitis
Milder winters, warmer summers, cooler falls	Extended transmission season, increased overwinter survival, range expansion, more frequent opportunities for transmission	WNv, Eastern equine encephalitis

Adaptation and adaptive capacity

Given current CO_2 emissions in the atmosphere over the 400 parts per million mark and the threat of global warming passing the 2°C threshold, anticipatory adaptation is seen as an optimal response to projected changes in order to reduce the worst effects of CC (22). Predicted impacts of CC will vary widely by region (23) and planned adaptation to these impacts consequently will need to vary widely as well (24). A recent review by Lesnikowski and colleagues (2011) reveals that most of the adaptation by Annex I countries (countries that committed themselves to reducing their greenhouse gas emissions

(GHG) under the Kyoto Protocol(25)) is currently focused on knowledge building and planning stages; however some actions are starting to be put into place.

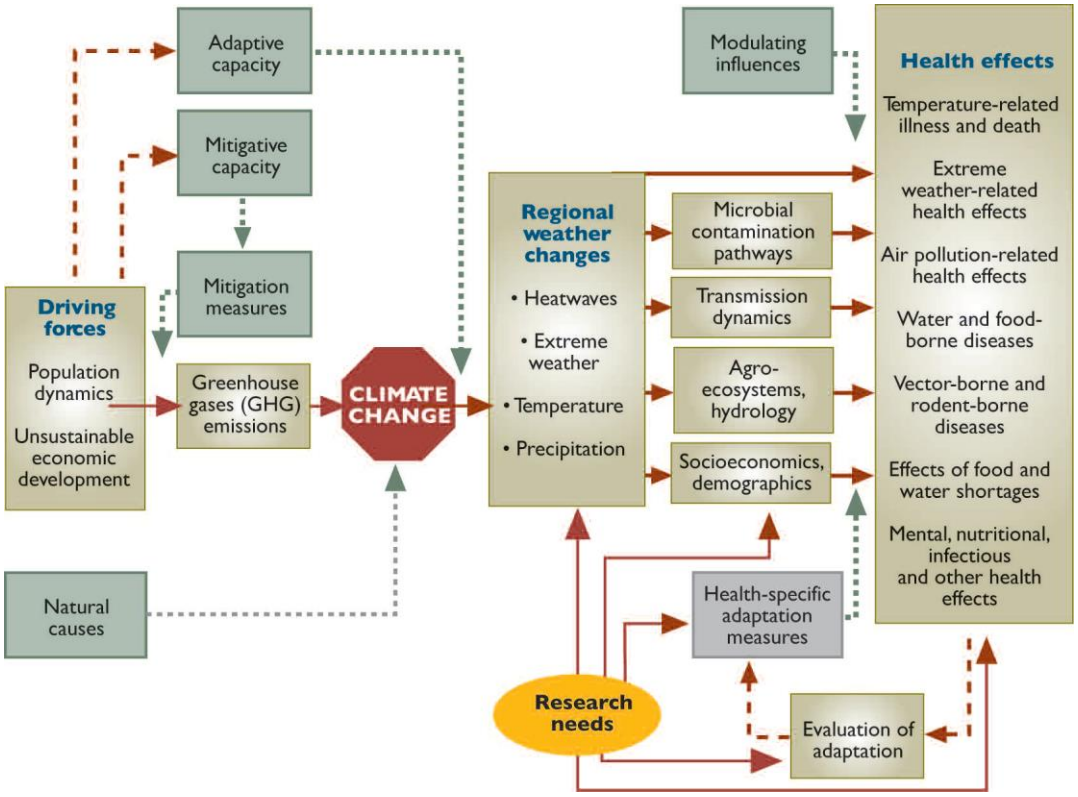


Figure 1. Conceptual overview of relationship between climate and infectious diseases [80]

In assessing adaptation options and policy, the relevant affected sectors need to be included in the discussion and pertinent evaluation criteria need to be selected in order to properly assess the options proposed. Criteria should be complete, operational (comparable) mutually independent and non-redundant (22). Füssel (2006) suggests the following criteria be considered: social determinants of vulnerability, current vulnerability to climate variability addressed, compatibility with existing policy goals, feasibility, and estimated burden of disease avoided. Social determinants of vulnerability are similar to social determinants of health, but will vary depending on the specific health outcome being examined (26). In their study on adaptation policy in the Netherlands, de Bruin and colleagues (2009) used the following criteria: the importance of option in terms of expected gross benefits that can be obtained, the urgency of the option, the no-regret characteristics of the option (good to do irrespective of CC), the co-benefits to other sectors and domains, the effect on climate mitigation (e.g. land use changes that reduce emissions as side effect) and in a separate evaluation, the 3-part feasibility of an option, scored their technical, societal and institutional complexity (22).

According to Klein (27), adaptation can be planned and proactive in advance of anticipated changes or it can be reactive following the occurrence of events. Planned adaptation consists of 4 steps: 1) information collecting and awareness building, 2) planning and design, 3) implementation, and 4) monitoring and evaluation (27). In order to improve proactive planned public health adaptation, it is important to assess the current knowledge and awareness of the general public to CSIDs. Furthermore, as adaptation and vulnerability are inextricably linked, it is important to assess the potential adaptive capacity of a population in order to improve adaptation planning where this capacity is low. Socio-

economic factors are generally used as the prime indicators of adaptive capacity, however, taking into account socio-cognitive factors is thought to provide a more accurate reflection of what behaviours individuals will actually adopt (28).

Multi-criteria decision aid (MCDA) and public health

At its broadest level, public health is concerned with the prevention and control of disease through a range of activities (29) including surveillance and policy making for the promotion of healthy behaviours, healthy communities and healthy environments. These broad objectives of public health can be loosely categorized into risk assessment (e.g. surveillance, drug evaluation, etc) and risk management (e.g. policymaking, priority setting, etc) types of activities. A number of frameworks have been proposed for the evaluation of health risks where the common elements include defining the health problem in its (broad) context, analyzing the risks associated with the problem, examining the options for addressing the risks, making decisions about which options to implement, applying the selected options and evaluating the results all within a process that allows for step iteration and involvement of stakeholders. Multi-criteria decision aid (MCDA) (sometimes referred to as multi-criteria decision analysis or multi-criteria decision making – but here we will use multi-criteria decision aid to refer to the process and multi-criteria decision analysis to refer to the actual analysis step in the process) is a decision support framework that has its origins in the field of operations research and has been used in a wide number of disciplines ranging from environmental management (30,31), agriculture (32), transportation and urban planning (33,34), and to a limited extent in public health (35,36).

MCDA can be performed with a single actor or decision-maker involved in the process or can be extended for use in a group decision context with multiple stakeholders (37). MCDA provides transparency and support for multiple stakeholder participation in order to evaluate a set of alternatives using both quantitative and qualitative criteria. MCDA assists decision makers and stakeholders in the search for mutually acceptable solutions by identifying similarities and differences in stakeholders' value systems and helping with the structuring and reflection of the decision problem by highlighting strengths and weaknesses in the alternatives under consideration. MCDA based approaches begin with an intelligence phase where the problem definition, decision constraints and evaluation criteria are defined. This is followed by a design phase where the list of possible alternatives and decision-makers' preferences are made explicit. The final phase, the "decision or recommendation" phase, consists of applying the decision rules and sensitivity analysis in order to produce a recommendation. The MCDA process is highly compatible with various risk assessment frameworks used in Public Health (38). The intelligence phase of MCDA can accommodate the problem definition, risk assessment and option identification steps while the design phase of MCDA can accommodate the strategy selection step. Although the evaluation of results may not correspond exactly to the final "decision or recommendation" phase of a typical MCDA, this step is not incompatible with the final phase of MCDA and can easily be added to this phase.

The compatibility between MCDA processes and Public Health risk assessment and risk management needs has been recognized by authors in the Public Health literature. A recent search of the literature for studies describing comprehensive MCDA use in Public Health found 12, 6 of which were performed in Europe, 3 in North America, and the other 3 in South America, Asia and Africa. According to Baltussen and Niessen (2006) (35), and based on surveys of the literature, there has been a limited exploration of MCDA in public health and health care to date; however, many of the studies from the field of environmental management that have made use of MCDA have had Public Health implications (e.g.: healthcare site selection (39), waste management (40–42) and various forms of toxic site selection (43,44), flood management and risk assessment (45–47)). Of those public health related

papers that have broached the topic of MCDA, few have engaged in a comprehensive MCDA process, most refer to MCDA to illustrate its principles (35,36,46,48,49) or identify and weight criteria for priority setting and other public health related decision making (50). Decision type problems in public health that have made use of MCDA range from risk assessments of various kinds (health technology (51,52), drug (53), pathogen (50), treatment alternatives), policy making and priority setting (38,54–59), risk management and diagnosis and health care (60,61).

4. Methodology / data

A cross-sectional study design was used to examine disease prioritization and adaptation preparedness via intervention prioritization in the face of climate sensitive infectious diseases (CSIDs) for populations living in southern Quebec (Canada) and Burkina Faso (West Africa). The main study consisted of two parts: 1) a disease prioritization exercise and an, 2) intervention prioritization exercise. This was followed by a comparison between the regions. The project aimed to understand concerns of interest in prioritizing diseases and interventions in the respective regions. All parts of the research project were conducted successively between January 1st 2014 and June 2016. A validation exercise examining the portability of an existing decision aid model to another region (Manitoba, Canada) was also carried out as a part of a fall back project.

Disease prioritization

A cross-sectional comparison of criteria selected for climate sensitive infectious diseases priority setting was carried out in Quebec (QC) and Burkina (BF) using a participatory decision-aid approach. Criteria selected at both sites were compared in order to identify commonalities and specificities of perspectives for prioritization of climate sensitive infectious diseases with the overall goal of reducing their public health impact and to examine the potential effect of criteria on disease prioritization results. The results of this comparison have been published and are available in the appendix (62). An overview of the results is presented below.

A comprehensive review of the literature was conducted to assess current knowledge on CSIDs posing a threat or with the potential to become a threat to southern Quebec (Canada). A thorough search of online article databases including PubMed and WebOfScience databases was performed using keywords to identify articles published within the last 10 years relating to CSIDs of concern for Quebec. Keywords such as “Climate sensitive infectious diseases”, “Quebec”, “Canada” were used in combination with specific diseases to identify articles of interest. This review of the literature was used to inform the multi-criteria phase of the project.

Multi-criteria decision analysis

An evaluation and pilot prioritization of diseases was performed using a participatory multi-criteria decision aid process (MCDA) (see Fig.2 adapted from (62)). Multi-criteria decision analysis is a decision aid approach that allows the comparison of multiple actions based on multiple, potentially conflicting criteria. The MCDA process consists of 12 steps including (Fig 2): 1) Problem definition, 2) Identification of scenarios (if applicable), 3) Identification of stakeholders, 4) Identification of potential actions/alternatives (diseases or interventions in this case), 5), Identification of key decision issues and translation into criteria, 6) Weighting of criteria, 7) Gathering of evidence, 8) Evaluation of actions over all identified criteria, 9) Multi-criteria decision analysis, 10) Sensitivity analysis, 11), Interpretation of results, 12) Presentation and review.

The MCDA process consists of two main parts, a problem structuring component (steps 1-8) and a decision analysis component (steps 9-12). Stakeholders are invited to participate in the process. Focus group discussions are held to define the problem, discuss the key decision issues, and define appropriate criteria and categories as well as measurement scales for these. An evaluation of the performance of the identified items was performed by the researchers and submitted to the stakeholders for review. Stakeholders were asked to weight the criteria according to their value preferences and in line with their organisational affiliations. The decision analysis phase of the process was performed using multicriteria decision analysis software to analyse and rank decision alternatives. Following this a sensitivity analysis was performed on the results to examine the robustness of the ranking outcome and the results were interpreted and discussed with stakeholders.

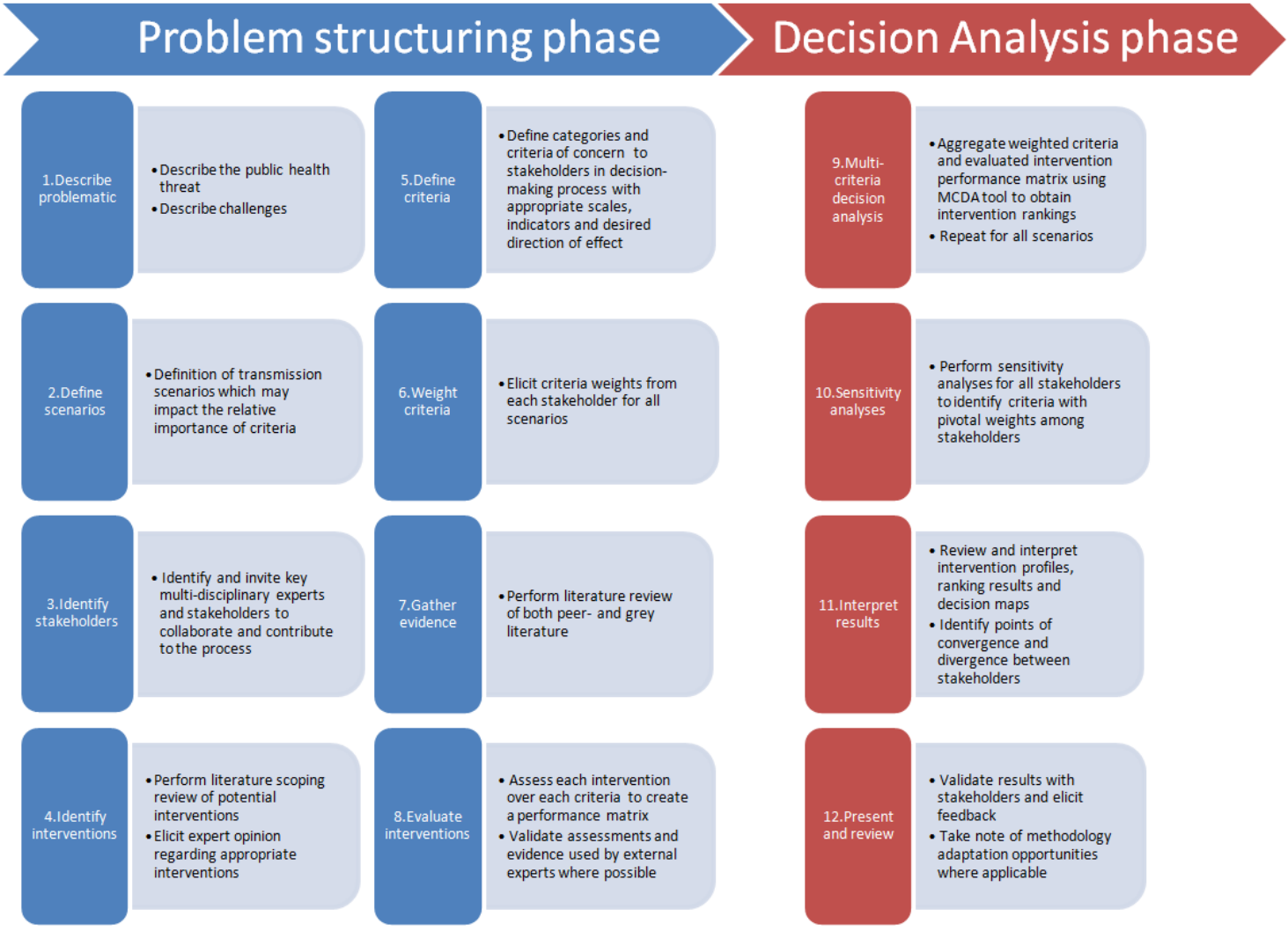


Figure 2. Steps in a multi-criteria decision analysis (MCDA) process (see (63))

Stakeholders

For the disease prioritization phase of the project, stakeholder consultation sessions were organized both in Quebec and Burkina Faso using a convenience sample of actors. In Quebec, this consultation

session was held in September 2014 in Montreal, Quebec at the Quebec national institute for public health (Institut National de Santé Public du Québec, INSPQ) office in Montreal. In Burkina Faso, this consultation session was held in February 2015 in Ouagadougou at the Université Aube Nouvelle. Invitations to attend the sessions were sent out to actors that had either previously been involved in giving feedback on the acceptability of government interventions for the province of Quebec or who had experience in various aspects relating to infectious disease or environmental management in Burkina Faso.

Two main focus group discussions (FGD) were held with 12-15 local stakeholders in each of the two study regions (Quebec and Burkina Faso). FGDs are a recognized qualitative research method used for data collection (63). FGDs promote group interaction encouraging participants to talk to one another in order to generate information on a particular subject (63). This method is known to be useful for exploring knowledge and experiences of importance to participants on a subject with the use of open ended questions (63). Notes were taken during the focus group discussions and recordings were made of discussions following written informed consent from participants. The goals of the FGDs were presented to the group at the start of the meeting and confidentiality of responses was assured.

Following agreement on a list of decision criteria for disease prioritization, stakeholders were asked to weight these criteria in order to produce a portrait of their value preferences pertaining to CSID prioritization. Stakeholders were given a Microsoft Excel spreadsheet tool with instructions asking them to distribute 100 points among all the criteria categories. Following this, stakeholders were then asked to redistribute 100 points within each category across all criteria. The spreadsheet tool automatically calculated the absolute weights of criteria. As a final step in the weighting process, stakeholders were asked to verify that the relative weights between criteria accurately reflected their values.

The PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations) method was used in all multi-criteria decision analysis phases. The PROMETHEE method calculates a score for each action based on the evaluation values given to each action, the weights expressed by stakeholders and pair wise comparison of the number of times an action is preferred over all other actions. The resulting list is an ordered ranking of the actions listed from the most preferred action to the least preferred action by all stakeholders (the group) in accordance with the evaluations given and weights expressed by stakeholders.

Analysis of the performance and criteria weights was performed using the visual PROMETHEE software (version 1.4.0.0) and the D-Sight software (version 3.3.2, D-Sight Company). Geometrical analysis for interactive aid (GAIA) analysis maps, available with both the D-Sight software and visual PROMETHEE software, were also used to aid in visual interpretation of results.

Comparison between study regions

A comparison between the two study regions, Quebec and Burkina Faso was performed to examine generalizable elements versus specific ones with regards to climate sensitive infectious disease prioritization. An initial model was created first with stakeholders in Quebec and then validated and discussed with stakeholders in Burkina Faso. The weighting of criteria retained as relevant for the two study regions were graphically compared. Criteria and categories were compared where possible between the two study regions. The FGDs were also used to contextualize the differences between the two regions.

Intervention prioritization

For the second part of this project, in order to assess adaptation management to CSIDs, a specific vector-borne disease was selected in each study region to prioritize focused intervention options. West Nile virus, a mosquito-borne disease endemic in Quebec, was selected for this region and malaria, another mosquito-borne disease endemic in Burkina Faso, was selected for this later region. Cross-sectional approaches were adopted to examine criteria and interventions appropriate for the management of a mosquito-borne infectious disease in Quebec (West Nile virus) and Burkina Faso (malaria). Criteria selected at both sites were compared in order to identify commonalities and specificities of perspectives across regions and examine the potential effect of criteria on intervention prioritization results. The results of each region's intervention management results have been submitted for publication and are currently under review. An overview of these results is presented below.

In the Quebec context, multiple transmission scenarios were defined to evaluate whether priorities changed under increased transmission intensity. These transmission scenarios are described in Appendix 1. In the Burkina Faso context, only the current transmission scenario was evaluated following discussion with stakeholders and in coherence with the existing challenges already occurring with infectious disease management in this region.

Additionally, as part of a fall back plan, a validation exercise was carried out in Manitoba to assess and discuss the applicability and modifications required to adapt a previously constructed Lyme disease model from Quebec to a Manitoban context. Lyme disease is an emerging vector-borne disease in Canada caused by *Borrelia burgdorferi* and transmitted by black legged ticks (*Ixodes scapularis* primarily on the east coast and *Ixodes pacificus* and *Ixodes angustus* on the west coast). Lyme disease has been a reportable disease in the province of Quebec since 2003 and has been reportable in Manitoba since 2009. Due to the relatively recent emergence of Lyme disease in Quebec, a pilot project was initiated in 2010 using a multi-criteria decision analysis approach (MCDA) to examine potential management strategies for the disease in the province. Four Lyme disease management decision aid models were constructed as part of the pilot project conducted in Quebec between 2010 and 2012 with a team of researchers from the Université du Quebec à Montréal (UQAM), and the Université de Montréal (UdeM). These models included models to prioritize risk communication actions for the general public and health professionals, prioritize surveillance actions and prioritize prevention and control interventions. These results are also included in the current report.

A comprehensive review of the literature was first conducted to assess current knowledge of West Nile virus specific interventions in Quebec and malaria specific interventions for Burkina Faso. This literature informed evidence was used to identify potential interventions and their relative effectiveness in reducing risk associated with the diseases specific to each study region. Additionally, a literature review was conducted to assess specific information relative to Lyme disease management in Manitoba.

In the case of Quebec and Burkina Faso, the preliminary literature review was conducted to construct an initial list of interventions appropriate for each disease and region for discussion with stakeholders (64–69). Interventions including active and passive surveillance, large scale and targeted communication campaigns and various prevention and control interventions were included in this preliminary list. Interventions under development and implementable under both a short and long-term perspectives were included in order to provide a range of options to cover all transmission scenarios. A baseline, *status quo* intervention encompassing passive surveillance of human cases was also included. The proposed interventions were then discussed and validated with participating stakeholders during a focus group discussion. Individual feedback was solicited from all stakeholders following the discussion

by means of a Delphi survey during which stakeholders had the opportunity to suggest additional interventions previously missed (70). Consensus was not explicitly sought during this process; rather stakeholders agreed that an intervention would be retained in the model so long as at least one stakeholder deemed it pertinent to include.

Multi-criteria decision analysis

West Nile virus and malaria

For the Quebec and Burkina Faso phases of the project, focus group discussions (FGD) were held with 12-15 local stakeholders in each study region to discuss appropriate interventions as well as criteria to prioritize these interventions. A first FGD was held in Quebec in April 2014 to create the West Nile virus multi-criteria decision analysis model. This model was then presented and adapted for malaria during a FGD held with local stakeholders in Burkina Faso in February 2015.

In the province of Quebec, stakeholders already involved in WNV management from various levels of government, academia as well as from an existing expert committee on WNV in Quebec were invited to participate in the MCDA process in April 2014. In Burkina Faso, stakeholders with backgrounds in entomology, environmental management and public health were invited to participate. Discussions were held in February 2015 at the Université Aube Nouvelle. Stakeholders included individuals from the national program against malaria (PNLP), the national research and training center for malaria (CNRFP), national disease control organization, Operational planning, regional health authorities, mosquito control operations and independent researchers.

The evaluation and prioritization of the identified interventions was performed using a multi-criteria decision aid process (MCDA). The initial intervention decision-aid model was created with stakeholders in Quebec and then adapted and discussed with stakeholders in Burkina Faso.

Lyme disease

A collaboration with the Manitoba Health, Healthy Living & Seniors association was created in order to facilitate contact with a group of local experts for participation as stakeholders in the Lyme model project. Discussions were held with stakeholders to adapt the previously constructed Quebec Lyme model (71) and run a preliminary assessment of the interventions for Manitoba. Discussions with experts were held to adjust assessment scores to the Manitoban context. Follow-up surveys were conducted to finalize the list of actions and criteria to include in the model.

Scenario weighting

Manitoban stakeholders were invited to weight the list of criteria retained in the model according to two hypothetical transmission scenarios. The hypothetical transmission scenarios were not meant to represent historical situations, nor describe a scientific consensus on any true scenario, but rather were meant to describe hypothetical situations. Scenario 1 was a hypothetical low incidence transmission scenario roughly equivalent to the current status of Lyme disease transmission in Manitoba. Scenario 2 was a hypothetical high incidence transmission scenario. The contextual details describing these two hypothetical transmission scenarios are shown in table 2.

The results of this consultation and follow-up steps contributed to the data required for preliminary analysis of prevention and control interventions for the management of Lyme disease in Manitoba. The modifications to the original Quebec model and resulting preliminary rankings resulting from the Manitoba modifications are described in the sections below. The evaluation and prioritization of the

identified interventions was once again performed using a multi-criteria decision aid process (MCDA) in visual PROMETHEE.

Table 2. Hypothetical Lyme disease transmission scenarios for criteria weighting

Scenario name	Scenario 1 Low incidence of Lyme disease in Manitoba	Scenario 2 High incidence of Lyme disease in Manitoba
Management context	The number of human cases of Lyme disease in Manitoba is between 20 and 30 per year. Media and the general public are starting to pay attention to the disease.	The number of human cases of Lyme disease in Manitoba has increased to over a 100 per year. Television, radio and written media have covered this disease multiple times and had many Lyme patients testify about their negative health effects as a result of acquired Lyme disease. Many calls are being received from concerned citizens following tick bites. You must make decisions regarding prevention and control actions to manage the disease in the province.
Current actions of the government	General Lyme disease prevention information available on the Manitoba health website and ongoing community outreach activities	General Lyme disease prevention information available on the Manitoba health website and ongoing community outreach activities
Scenario description	A few ticks have been submitted and found to be infected with *Borrelia burgdorferi* in highly populated regions of the province. A larger number of infected ticks are reported in less populated regions of the province.	*Borrelia burgdorferi* infected ticks are regularly submitted by the general public and regional veterinarians from highly populated regions of the province. Numerous cases of tick bites with bull's eye rash have been reported in the province

5. Results

Disease prioritization

Twenty—four stakeholders in total accepted the invitation to participate in the consultations held in September 2014 in Quebec (n=12) and in February 2015 in Burkina Faso (n=12). Effective criteria for prioritization of CSID threats and the likelihood of future changes within a 10-30-year time frame were discussed. A nominal group technique was used to help structure this discussion (72) and produce an ordered list of consensual criteria. Criteria identified during the FGD were synthesized and prioritization criteria were tested against a pilot list of diseases identified during the comprehensive literature review to produce an initial ranking of CSIDs of concern for southern Quebec. Both groups of stakeholders included medical doctors, entomologists, microbiologists, biologists, academic researchers and members of the public. Actors included participants from the following organizations in Quebec: Ministry of agriculture, forestry and food (MAPAQ), ministry of sustainable development, environment, parks and fauna (MDDEFP), regional public health authorities, sick patients advocate, municipal environmentalists and entomologists, microbiologists from provincial laboratories, and Independent researchers, University of Montreal. In Burkina Faso, actors included participants from the following organizations: Members from the national program against malaria (PNLP), The national research and training center for malaria (CNRFP), National disease control organization, Operational planning, regional health authorities, Mosquito control operations, and Independent researchers, University Aube Nouvelle.

Criteria

Table 3. Criteria for the prioritization of climate sensitive infectious diseases

Category	Criteria	Quebec (QC)	Burkina Faso (BF)
Public Health Criteria (PHC)	PHC-01 – Current incidence of human cases in country	X	X
	PHC-02 – Severity of the disease (both physically and mentally)	X	X
	PHC-03 – Vulnerable groups	X	X
	PHC-04 – Potential to increase social inequality *	X	
	PHC-05 – New disease †		X
Social Impact Criteria (SIC)	SIC-01 – Risk perception of the public	X	X
	SIC-02 – General level of knowledge, attitude and behaviour of the public	X	X
	SIC-03 – Risk perception of health workers †		X
	SIC-04 – Risk perception of decision makers†		X
	SIC-05 – International position with regards to the disease †		X
Risk and Epidemiology Criteria (REC)	REC-01 – Existence of favourable conditions for disease transmission	X	X
	REC-02 – Epidemic potential	X	X
	REC-03 – Current global trend of disease over last 5 years	X	X
	REC-04 – Proportion of susceptible population	X	X
Animal and Environmental Health Criteria (AEC)	AEC-01 – Incidence of animal cases	X	X
	AEC-02 – Severity of disease	X	X
	AEC-03 – Can infect environment	X	X
Economic Criteria (ECC)	ECC-01 – Cost to the government	X	X
	ECC-02 – Cost to private sector (and NGOs) †	X	X
	ECC-03 – Cost to individuals (and families) †	X	X
Strategic and Operational Criteria (SOC)	SOC-01 – Capacity to detect and diagnose	X	X
	SOC-02 – Existence and effectiveness of current treatments	X	X
	SOC-03 – Level of scientific knowledge of the disease	X	X
	SOC-04 – Optimization opportunities	X	X
	SOC-05– Reportable disease	X	X
	SOC-06 – Access to treatment†		X
	SOC-07 – Adequate conditions to treat the disease †		X

* Criteria added in Quebec (Canada)

† Criteria added or modified in Burkina Faso (Africa)

Drawing from previous work (71,73), a preliminary list of 15 evaluation criteria, distributed over five categories (“Public Health” criteria, “Social Impact” criteria, “Economic” criteria, “Strategic and Operational”, and “Animal and Environmental Health” criteria) was compiled by the research team. Each criterion was defined with a measurement scale (allowing for a quantitative or qualitative assessment of an intervention), including a direction of desired effect. Linear preference functions were used with all criteria and qualitative assessments were transformed into monotone ascending or descending scales

depending on the direction of the desired effect (74). The relevance of criteria and their measurement scales was discussed and validated with stakeholders. Individual feedback was also solicited via a Delphi survey (70). Once again, consensus was not explicitly sought regarding retained criteria; rather a criterion was retained so long as at least one stakeholder deemed it pertinent. Weights of zero were permitted by stakeholders to indicate absence of importance for a given criterion during the weighting process (described in the following section). Stakeholders were asked to weight criteria under all transmission scenarios. Scenarios were presented to stakeholders as hypothetical yet climatically plausible transmission scenarios meant to examine the effect of changing criteria trade-offs under different transmission intensities. The list of identified criteria and used in each region is presented in Table 3.

Table 4. Quebec stakeholder weights for all criteria

		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Public Health Criteria (PHC)	PHC1	6	6	5	5	8	5	11	6	5	14
	PHC2	4	12	10	13	2	5	12	6	4	5
	PHC3	8	9	5	5	5	5	4.5	6	6	12
	PHC4	2	3	5	2	3	5	2.5	2	5	4
Social Impact Criteria (SIC)	SIC1	2.5	5	9	1	7.5	4	5	10	4	2
	SIC2	2.5	0	6	4	7.5	4	5	10	5	3
Risk and Epidemiology (REC)	REC1	9	8	3	5	10	5	6	5	6	9
	REC2	8	8	10	10	1	5	9	5	5	4
	REC3	8	8	10	5	2	5	5	5	4	2
	REC4	6	3	3	10	2	5	5	5	5	5
Animal and Environmental Health Criteria (AEC)	AEC1	4	3	3	2	5	6	2	2	4	3
	AEC2	4	3	3	4	5	6	2	4	4	1
	AEC3	3	3	5	4	5	6	2	4	5	1
Economic Criteria (ECC)	ECC1	2	2	4	6	8	6	2	1	4	9
	ECC2	2	2	2	2	5	5	2	1	4	5
	ECC3	2	2	4	2	2	6	2	1	5	2
Strategic and Operational Criteria (SOC)	SOC1	11	3	2	2	7	5	6	12	5	4
	SOC2	9	13	6	15	10	5	9	12	5	8
	SOC3	6	3	5	2	2	4	5	1	5	1
	SOC4	3	6	2	1	2	3	3	1	5	5
	SOC5	2	0	2	0	1	3	3	1	5	2

Due to time constraints and the time sequence in which the study steps were carried out, the model was initially developed with Quebec stakeholders and then presented and modified following discussions with stakeholders in Burkina Faso. The new criteria that were added for Burkina Faso were the following:

In the public health category:

- The potential to increase social inequality was removed
- New disease was added

In the social impact category:

- Risk perception of health workers was added

- Risk perception of decision makers was added
- International position with regards to the disease was added

In the strategic and operational impact category:

- Access to treatment was added
- Adequate conditions to treat the disease was added

Following discussions, stakeholders in both regions were asked to weight criteria in accordance with their value system using a pre-prepared excel spreadsheet tool with instructions provided as described in multi-criteria decision analysis methods section above.

Table 5. Burkina Faso stakeholder weights for all criteria

		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Public Health Criteria (PHC)	PHC1	20	16	2	7.9	3.2	5.4	7	4	14	11
	PHC2	12	12	1	4.5	14	4.5	10	2	0	12
	PHC3	4	8	1	3.4	2	2.7	4	1	0	6
	PHC4	4	4	1	6.8	1	5.4	1	1	1	1
Social Impact Criteria (SIC)	SIC1	1	2	1	3.3	6.5	3.2	5	5	7	6
	SIC2	1	3	2	1.3	1	3.5	0	0.5	1	1
	SIC3	1	2	3	3.9	1	3.5	0	0.5	1	1
	SIC4	5	2	2	3.3	2.8	2.8	3	2	3	0
	SIC5	2	1	2	1.3	14	4	2	2	5	6
Risk and Epidemiology (REC)	REC1	8	8	2	5	8	4.2	6	5	6.5	2
	REC2	6	4	2	6	1	4.2	0	4	1	2
	REC3	4	6	3	4	1	2.8	0	2	1	2
	REC4	2	2	3	5	6	2.8	7	6	6.5	4
Animal and Environmental Health Criteria (AEC)	AEC1	0.5	2	2	1.2	2	5.6	2	1	2	2
	AEC2	0.5	4	1	1.2	2	4.2	2	1	2	2
	AEC3	4	4	2	9.6	4	4.2	6	6	8	4
Economic Criteria (ECC)	ECC1	5.3	1.5	10	11	11	6.8	7	13	2	0
	ECC2	5.3	1	5	3.6	1.6	3.4	1	1.5	3	0
	ECC3	4.5	2.5	10	3.6	6.6	6.8	7	12	11	14
Strategic and Operational Criteria (SOC)	SOC1	0.5	6	13	2.3	3.2	2.6	10	4	8	0
	SOC2	0.5	3	7	2.1	2.3	3.6	6	5	4	5
	SOC3	4	1.5	7	2.3	0.5	3.6	2	4.5	2.5	2.5
	SOC4	3	1.5	5	2.1	0.5	2.6	2	4.5	2.5	2.5
	SOC5	1	1.5	7	2.1	1.2	3.6	5	9	4	9
	SOC6	0.5	0	4	2.1	0.5	2	0	0	1	0
	SOC7	0.5	1.5	2	2.1	3.4	2.2	5	3	3	5

Ten stakeholders in each respective region completed the disease prioritization criteria weighting exercise with results shown in tables 4 and 5. A comparison of the average category weights across the two regions is shown in Fig. 3. Mean criteria category weights were similar between both

regions except for the “Risk and Epidemiology” (p = 0.001) and “Economic” (p=0.008) criteria categories which were found to be significantly different.

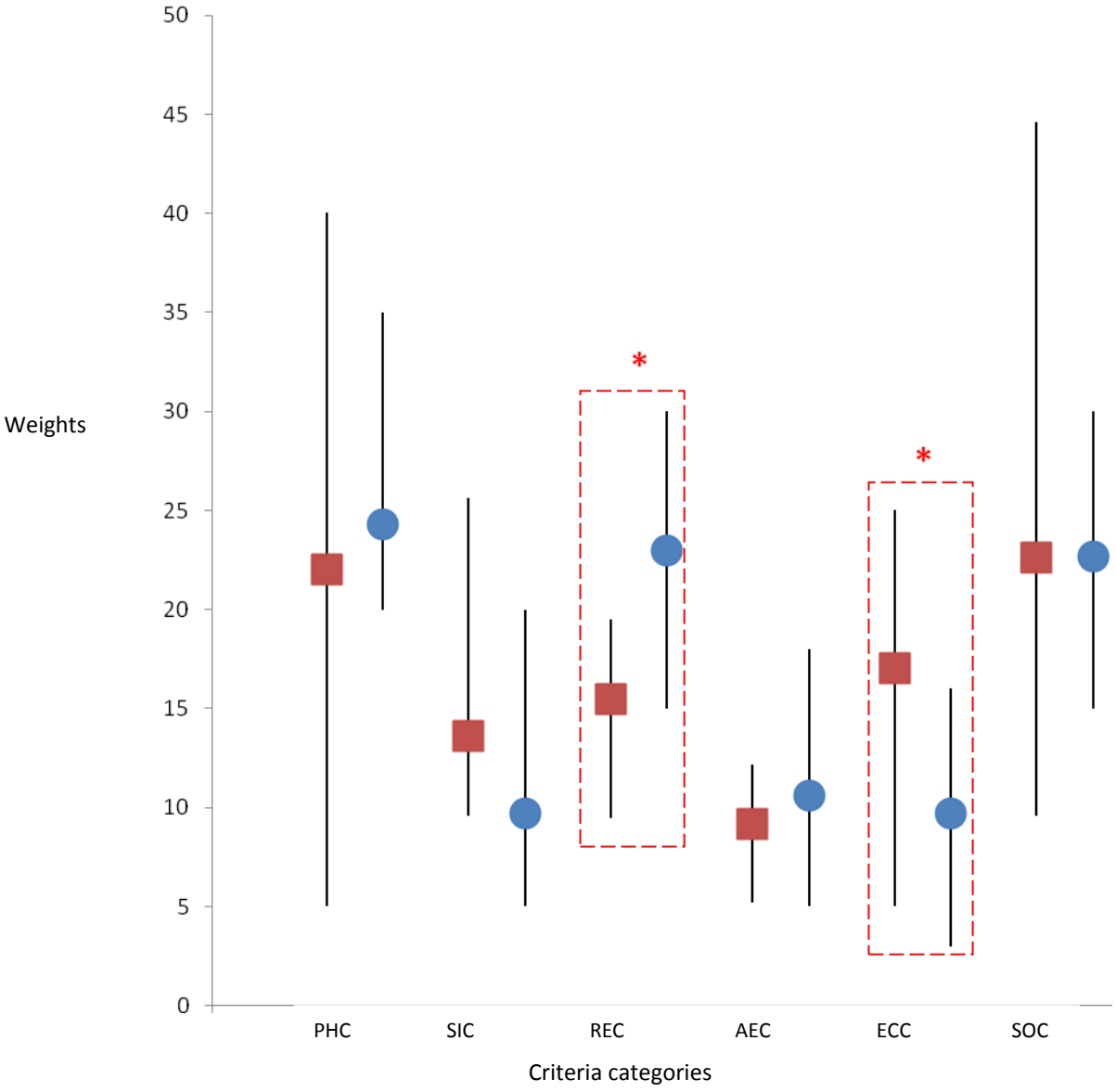


Figure 3. Average weighting of disease decision criteria categories by regions
(Burkina Faso represented by red square markers and Quebec represented by blue circular markers). Criteria categories are shown along the X axis and average weights by category are shown along the y axis. Bars indicate the stakeholder assigned weight ranges for criteria categories. The differences between the two groups (BF and QC) were found to be significant for the “Risk and Epidemiology” (REC) and “Economic” (ECC) categories only (unequal variance t-test, $p < 0.5$). Criteria category Legend: PHC: Public Health Criteria; SIC: Social Impact Criteria; REC: Risk and Epidemiology Criteria; AEC: Animal and Environmental Health Criteria; ECC: Economic Criteria; SOC: Strategic and Operational Criteria.

In QC, the "Public Health" criteria category received the highest weight average followed by "Risk and Epidemiology", "Strategic and Operational", "Animal and Environmental Health", "Economic" and "Social Impact" criteria categories the last two of which were tied for last place. In BF, "Strategic and Operational" category received the highest weight average for the group of stakeholders followed by, "Public Health", "Economic", "Risk and Epidemiology", "Social Impact" and "Animal and Environmental Health" criteria categories.

The weight span for categories was generally narrower among stakeholders in QC. The range from minimum to maximum weight per category spans approximately 15 points for all categories by QC stakeholders whereas the weight ranges span from 5 to 35 for categories by stakeholders in BF (Figure 3). The two categories with the largest weight discrepancy in BF were the "Public Health" criteria category and the "Strategic and Operational Criteria" category, both of which were also the highest weighted categories overall for this region.

Pilot prioritization

An exploratory prioritization of five mosquito-borne diseases, chikungunya (*CHIKV*), dengue (*DENV*), lymphatic filariasis (*LF*), malaria (*MAL*) and West Nile virus (*WNV*) was carried out to examine the effects of criteria weightings on disease ranking in both QC and BF contexts. Mosquito-borne diseases were chosen as mosquitoes are poikilotherms unable to regulate their own temperatures and resulting sensitivity to climatic parameters (4,75). The five pilot diseases, *CHIKV*, *DENV, LF, MAL*, and *WNV* were assessed using context specific data for each region obtained in the literature and via discussion with stakeholders.

Participating stakeholders were asked to weight criteria and a literature search was conducted in order to assess and score performance of diseases on all criteria contextualized for the two regions. Analysis of the performance and criteria weights was performed with the PROMETHEE method in visual PROMETHEE software (version 1.4.0.0). The resulting data and weights were analyzed using a MCDA framework and resulted in differences in the relative importance (i.e. prioritized importance) of the diseases between the two regions. In QC, the resulting disease prioritization order was: *WNV, MAL, DENV, CHIKV* and *LF,* while in BF, the resulting disease prioritization order was: *DENV, MAL, CHIKV, LF* and *WNV*.

Table 6. Pilot climate sensitive infectious disease criteria evaluations for Quebec

	Criteria																					
	PHC1	**PHC2**	**PHC3**	**PHC4**	**SIC1**	**SIC2**	**REC1**	**REC2**	**REC3**	**REC4**	**AEC1**	**AEC2**	**AEC3**	**ECC1**	**ECC2**	**ECC3**	**SOC1**	**SOC2**	**SOC3**	**SOC4**	**SOC5**
MAL	0	4	1	1	2	1	3	1	1	5	0	0	2	2	1	1	1	2	3	1	1
DENV	0	4	0	1	1	1	1	1	3	5	0	1	2	2	1	1	1	1	3	1	0
LF	0	3	0	1	1	1	2	2	1	5	0	1	2	1	1	1	1	2	3	1	0
CHIKV	0	2	0	1	1	1	1	1	3	5	0	2	2	1	1	1	1	0	2	1	0
WNv	1	2	1	1	1	2	3	2	1	5	6	4	2	2	1	1	1	0	3	1	1

Disease evaluation matrix showing evaluation scores for each of the five pilot diseases based on context specific data reviewed pertaining to each disease over all criteria.

Note: Criteria PHC4, REC4, AEC3, ECC2, ECC3, SOC1, SOC4 non-discriminating with the above data set due to lack of variation between diseases but could be discriminating with different diseases or more refined data set. Criteria were retained in the model due to expressed interest of stakeholders.

Table 7. Pilot climate sensitive infectious disease criteria evaluations for Burkina Faso

	Criteria																										
	PH	PHC	PHC	PHC	SIC	SIC	SIC	SIC	SIC	REC	REC	REC	REC	AEC	AEC	AEC	ECC	ECC	ECC	SOC	SOC	SOC	SOC	SOC	SOC	SOC
	C1	2	3	5	1	2	3	4	5	1	2	3	4	1	2	3	1	2	3	1	2	3	4	5	6	7
MAL	4	4	1	0	3	3	2	3	2	3	2	1	5	0	0	2	3	3	2	1	2	3	1	1	1	1
DENV	6	4	0	0	2	2	2	1	1	3	2	2	5	6	1	2	2	2	2	1	1	3	1	1	1	1
LF	4	3	0	0	2	2	1	1	1	3	2	1	5	6	1	2	2	2	2	1	2	3	1	1	2	2
CHIKV	6	2	0	0	1	1	1	1	2	3	2	3	5	6	2	2	2	2	2	1	0	2	1	0	1	1
WNv	6	2	0	0	1	1	1	1	1	3	2	1	5	5	4	2	1	1	1	1	0	3	1	0	1	1

Disease evaluation matrix showing evaluation scores for each of the five pilot diseases based on context specific data reviewed pertaining to each disease over all criteria.

Note: Criteria PHC5, REC1, REC2, REC4, AEC3, SOC1, SOC4 non-discriminating with the above data set due to lack of variation between diseases but could be discriminating with different diseases or more refined data set. Criteria were retained in the model due to expressed interest of stakeholders.

Intervention Prioritization

West Nile virus in Quebec

Twelve stakeholders participated in the West Nile virus management discussions held in Quebec following which 23 interventions (Table 8) and 18 evaluation criteria were retained (Table 9). Interventions included individual protective measures, mosquito source reduction measures, adult mosquito control measures, and interventions aimed at the animal reservoir.

Table 8. Interventions for the management of WNV in QC

Individual levels interventions		
Code	**Interventions**	**Description**
INT-I1	Use of mosquito repellent	Ex.: DEET, p-menthane-3,8-diol applied to skin
INT-I2	Use of domestic insecticides	Ex.: aerosols, torches, spirals, etc.
INT-I3	Use of alternative technologies	Ex.: automatic insecticide dispensers, electric traps, etc.
INT-I4	Wearing light colored, long clothing	Use of robust and tightly woven fabric
INT-I5	Reducing outdoor activities	Reduce outdoor activities in high risk areas at dusk and dawn
INT-I6	Reinforcing the immune system	Via healthy living and lifestyle
INT-I7	Inspecting window screen integrity	Install and inspect integrity of screens on windows and doors
INT-I8	Human vaccination	Alternative in development
INT-I9	Wearing insecticide treated clothing*	Insecticide treated clothing
INT- I18	Eliminating peridomestic larval sites	Stagnant water, rain water barrels, pails, pool covers, drains
Regional level interventions		
Code	**Interventions**	**Description**
INT-R1	Modification of natural larval sites	Ex.: water banks, swamps, marshes,
INT-R2	Modification of man-made larval sites	Ex.: treated water basins, reservoirs, damns, roadside ditches, catch basins, underground water canals, vacant and commercial lots, snow disposal sites, used tire sites
INT-R3	Use of parasites and micro-organisms	Use of parasites and pathogenic micro-organisms Ex.: nematodes, mushrooms
INT-R4	larvicides	Ground application of larvicides at identified mosquito breeding sites
INT-R5	Use of mosquito predators	Ex.: birds, bats, fish, insects
INT-R6	Dissemination of sterile males	Use of sterile male mosquitoes or other compatible insects
INT-R7	Use of lethal ovitraps #	Traps destined for females with lethal liquid

INT-R8	Use of adulticides	Treatment by truck or plane
INT-R9	Vaccination of animal reservoir	Vaccination of the main animal reservoir Ex.: vaccination of American blackbirds
INT-R10	Reduction of the main animal reservoir #	Ex.: controlled reduction of American blackbirds
INT-R11	Modification of animal reservoir habitat #	Ex.: move American blackbird dormitories away from inhabited areas
INT-R12	Increase biodiversity at peridomestic level #	Ex.: attract other birds near habitat (to reduce circulating levels of the virus)
INT-R13	Status quo – Human passive surveillance	Encourage research and knowledge transfer regarding control and prevention methods
INT-R14	Large scale communication campaign †	Ex.: media campaign, social media, etc
INT-R15	Targeted communication campaign †	Ex.: health professionals (detection of new cases)
INT-R16	Active surveillance †	Ex.: mosquitoes, birds, human cases

intervention not assessed due to insufficient information in the literature
† intervention not included in current model

Although communication and surveillance interventions were explicitly recognized as important elements within a VBZD management programme by stakeholders, these interventions were not included in the current model due to concerns regarding the ability to properly assess the efficacy of these interventions under one comprehensive model. The consensus was to explore these interventions separately in a future exercise.

Table 9. Criteria for the management of West Nile virus in Quebec.

Category	WNV criteria	Description
Public Health Criteria (PHC)		
	PHC1 - Incidence reduction	Reduction in incidence of human cases
	PHC2 - Entomological risk reduction	Reduction of entomological risk
	PHC3 –Physical health impact	Impacts to human physical health
	PHC4 - Mental health impact	Impacts to human mental health
	PHC5 – Social equity	Impact on social equity
	PHC6 – Reduction of circulating virus	Reduction in level of circulating virus in animal reservoir
	PHC7 – Proportion affected	Proportion of population that benefits from the action
Social Impact Criteria (SIC)		
	SIC1 – Public acceptance	Level of public acceptance
	SIC2 – Impact to credibility	Impact to confidence in and credibility of organisation in charge
Economic Criteria (ECC)		
	ECC1 – Government cost	Cost to the government
	ECC2 – Municipal cost	Cost to municipalities
	ECC3 – Individual cost	Cost to individuals
Strategic & Operational Criteria (SOC)		
	SOC1 - Delay	Delay before appearance of desired effect
	SOC2 – Complexity	Institutional and operational complexity of the action
	SOC3 – Sustainability	Sustainability of the action
	SOC4 – Other policy impact	Impact on other public policies
Animal & Environmental Criteria (AEC)		
	AEC1 – Animal health impact	Impact on animal health
	AEC2 – Environmental impact	

Stakeholder weights for the criteria for the first transmission scenario are presented in table 10. Weights for additional scenarios are included in the supplementary material (see Appendix 2). The criteria deemed most important (most points attributed per criterion by stakeholders), were predominantly criteria related to the "Public Health" category, followed by the "Economic" category or the "Strategic and Operational" criteria category. In nearly all transmission scenarios, "Animal and Environmental Health" criteria ranked lowest, with fewest weights attributed by stakeholders. Within the "Public Health" category, a majority of weights were attributed to the "incidence reduction" criterion, and "physical health impact" criterion. Within the "Social Impact" category, the "credibility impact" criterion received the highest weight in most scenarios. Within the "Economic" criteria category, the "government cost" criterion received the highest weight. Within the "Strategic and Operational" criteria category, the "delay" criterion was given highest weight for medium and high scenarios. Finally, in the "Animal and Environmental Health" criteria category, the "environmental impact" criterion was given the highest weight for all scenarios.

Assessments were performed for all interventions over all criteria using measurement scales discussed and finalized with stakeholders. Evaluations were based on existing peer-reviewed evidence, grey literature and available data. When data was not available for an evaluation, expert judgment was used. All information relative to the evaluations was compiled into an assessment matrix then revised and discussed by all evaluators. Assessments were further reviewed and validated by external experts with specific field or research experience.

Table 10. Criteria weighting by QC stakeholders

		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
Public Health Criteria (PHC)	PHC1	16	9	10	5	11	16	15	16	6.25	6.67	16.8
	PHC2	8	3	10	5	11	6	0	8	5	6.67	4.8
	PHC3	4	3	5	5	3	10	20	6	7.5	6.67	2.4
	PHC4	4	3	5	5	3	2	10	2	1.25	6.67	0.96
	PHC5	2	3	5	5	1	2	2.5	4	1.25	6.67	2.4
	PHC6	2	3	5	5	1	2	0	0	1.88	6.67	4.8
	PHC7	4	6	10	20	20	2	2.5	4	1.88	26.7	15.84
Social Impact Criteria (SIC)	SIC1	2	7	5	5	2.5	5	5	10	6.4	0	3
	SIC2	3	3	5	5	2.5	5	5	0	1.6	0	7
Economic Criteria (ECC)	ECC1	7.5	5	7.5	6.25	6.8	10	6.25	7.5	44	8.33	8
	ECC2	2.5	5	5.25	6.25	6.6	7.5	6.25	3.75	8.25	8.33	7
	ECC3	15	10	2.25	12.5	6.6	7.5	12.5	3.75	2.75	16.7	5
Strategic and Operational Criteria (SOC)	SOC1	6	5.25	4	0	7.5	0.5	2.5	5	3	0	5
	SOC2	4	2.25	7	7.5	3.75	1	2.5	7.5	3	0	4
	SOC3	8	6	7	7.5	1.95	3	2.5	5	2.5	0	5
	SOC4	2	1.5	2	0	1.8	0.5	2.5	7.5	1.5	0	6
Animal and Environmental Health Criteria (AEC)	AEC1	5	10	2.5	0	5	10	2.5	5	0.8	0	1.2
	AEC2	5	15	2.5	0	5	10	2.5	5	1.2	0	0.8

Multi-criteria decision analysis for Quebec

Two main sets of analyses were performed, one based on individual-level interventions (n=11) and the second based on regional-level interventions (n=10). For the purpose of exploratory

comparison, an analysis of combined individual-level and regional-level interventions was also performed. Following this, sensitivity analyses were performed on all criteria and for all stakeholders to examine the robustness of rankings and identify potentially weight-sensitive criteria.

Global results

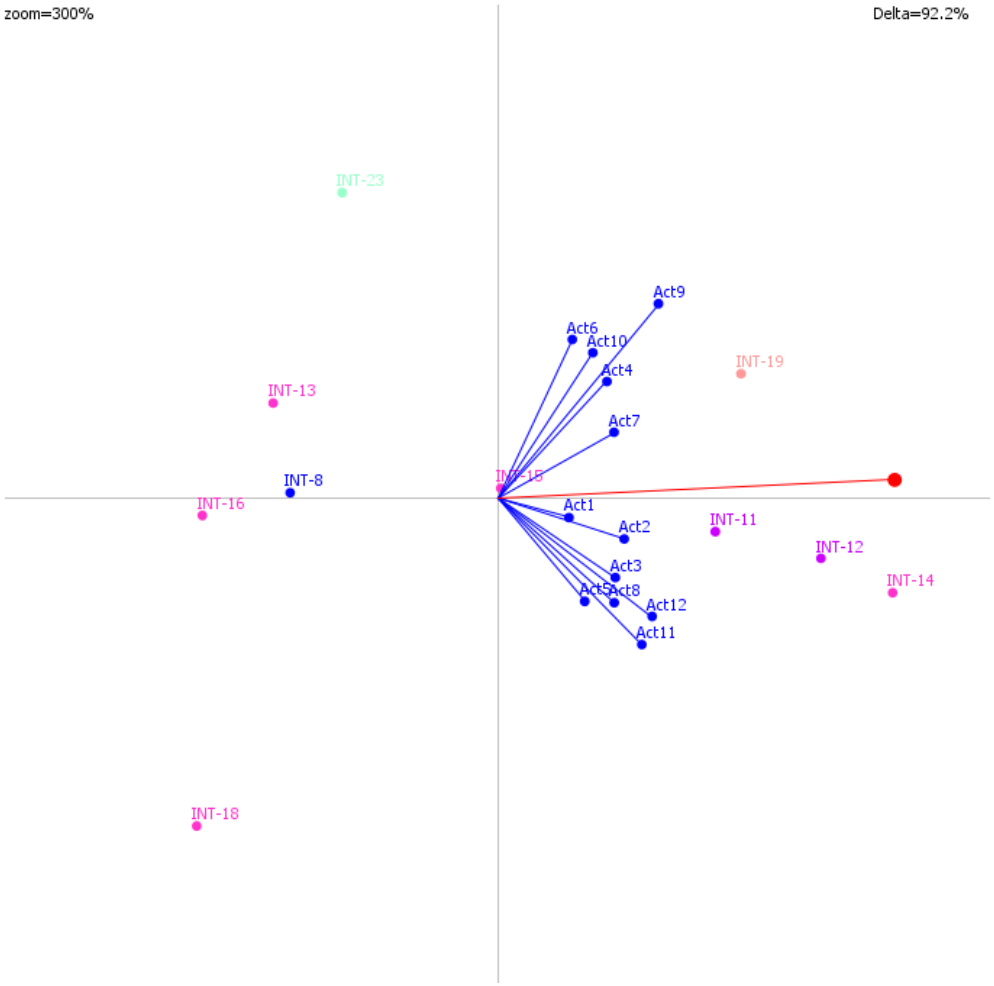


Figure 4. GAIA decision map for QC regional-level model

A strong level of congruence was generally observed among weights expressed by stakeholders across all scenarios. The high-risk transmission scenario analysis of regional-level interventions illustrates this (Fig 4). In figure 4, two semi-coalitions of stakeholders can be observed consisting in one case of stakeholders 4,5,7,9 and 10 and in the second case of stakeholders 1,2,3,5,8,11 and 12. Stakeholder positions are generally all pointing in the same direction as the decision axis indicating that no stakeholders is in direct opposition to the group consensus; however slight differences between these two groups of stakeholder weights can be observed. A statistical comparison of weights (Welch's t-test, unequal variances) revealed that these two groups of stakeholders had significant differences in weights for the Social impact category (p=0.015) as well as the Animal and Environmental Health criteria category (p=0.04). From an organizational standpoint, stakeholders in the 2nd coalition consist of a mix of organizations including public health, wildlife and environmental management. The 1st coalition consists of a mix of wildlife and public health related organizations. The bigger difference between these

two groups may be their spatial planning mandates with stakeholders in coalition 2 having more involvement in daily field operations and stakeholders from coalition 1 being more involved at a regional planning scale, though not strictly so. Both points of view are important to take into account and despite their differences in weighting; there is a consensus with regards to recommended interventions. Stakeholder positions were seen to converge under scenarios of increasing severity. Sensitivity analyses were performed to examine the robustness of weights given by stakeholders to criteria in the models and their effect on the overall rankings. The criteria most sensitive to stakeholder weights primarily consisted of criteria from the "Public Health" category, as well as the "credibility impact" criterion, "individual cost" criterion and "government cost" criterion.

Individual level interventions for Quebec

Table 11. Ranking of the individual-level protection interventions for QC.

Scenarios	Low risk				Medium risk				High risk			
	1		2		3		4		5		6	
Intervention	Rank	Net Flow	Rank	Net Flow	Rank	Net Flow	Rank	Net Flow	Rank	Net Flow	Rank	Net Flow
INT-01 Use of mosquito repellent	5	-0	5	-0	6	-0	6	-0	6	-0.02	6	-0
INT-02 Use of domestic insecticides	8	-0.1	8	-0.1	7	-0.1	7	-0.1	8	-0.11	8	-0.1
INT-03 Use of alternative technologies	9	-0.1	9	-0.1	8	-0.1	9	-0.1	9	-0.11	9	-0.1
INT-04 Wearing light colored, long clothing	2	0.19	2	0.17	2	0.22	2	0.22	2	0.23	2	0.22
INT-05 Reduction of activities at peak times	4	0.09	4	0.07	4	0.09	4	0.08	4	0.09	4	0.08
INT-06 Reinforcing the immune system	6	-0	7	-0.1	9	-0.1	8	-0.1	7	-0.05	7	-0.1
INT-07 Inspecting window screen integrity	1	0.22	1	0.23	1	0.25	1	0.25	1	0.27	1	0.25
INT-08 Human vaccination	11	-0.2	11	-0.2	11	-0.2	11	-0.2	10	-0.19	10	-0.2
INT-09 Wearing insecticide treated clothing	7	-0	6	-0	5	0.01	5	0	5	0.03	5	0.01
INT-10 Eliminating peridomestic larval sites	3	0.12	3	0.11	3	0.11	3	0.1	3	0.10	3	0.11
INT-23 Status quo	10	-0.2	10	-0.1	10	-0.2	10	-0.2	11	-0.23	11	-0.2

The top four ranked personal protection interventions, inspecting window screen integrity, wearing lightly colored clothing, and eliminating peridomestic mosquito larval sites, reducing outdoor activities at peak times, were identical across all scenarios (Table 11). These rankings are based on evidence-based assessment scores combined with stakeholder assigned weights. Figure 5 shows how Inspecting window screen integrity scores high on a majority of criteria with the exception of "entomological risk reduction", "reduction of circulating virus" and "social equality" where it received lower scores. The second and third ranked interventions, wearing light colored clothing and eliminating peridomestic larval sites, also scored highly on a majority of criteria (Fig 5).

The least favoured interventions among this subset varied slightly from one transmission scenario to another, but generally included: *use of alternative technologies*, *human vaccination* and

status quo (Table 11). Examination of the profiles for the bottom ranked interventions, *status quo* and *human vaccination*, (Fig 5) shows how these interventions score poorly on most criteria including many "Public Health*"* criteria, a category consistently weighted highly by all stakeholders. *Human vaccination* in particular scores poorly over many criteria, notably "entomological risk reduction", "physical health impact", "social equity" (if not covered by universal health care, then some costs must be incurred by the general public for vaccination), "public acceptance", "credibility impact", "government cost", "individual cost", "delay", and "complexity" (highly complex since licensed human vaccine not yet available).

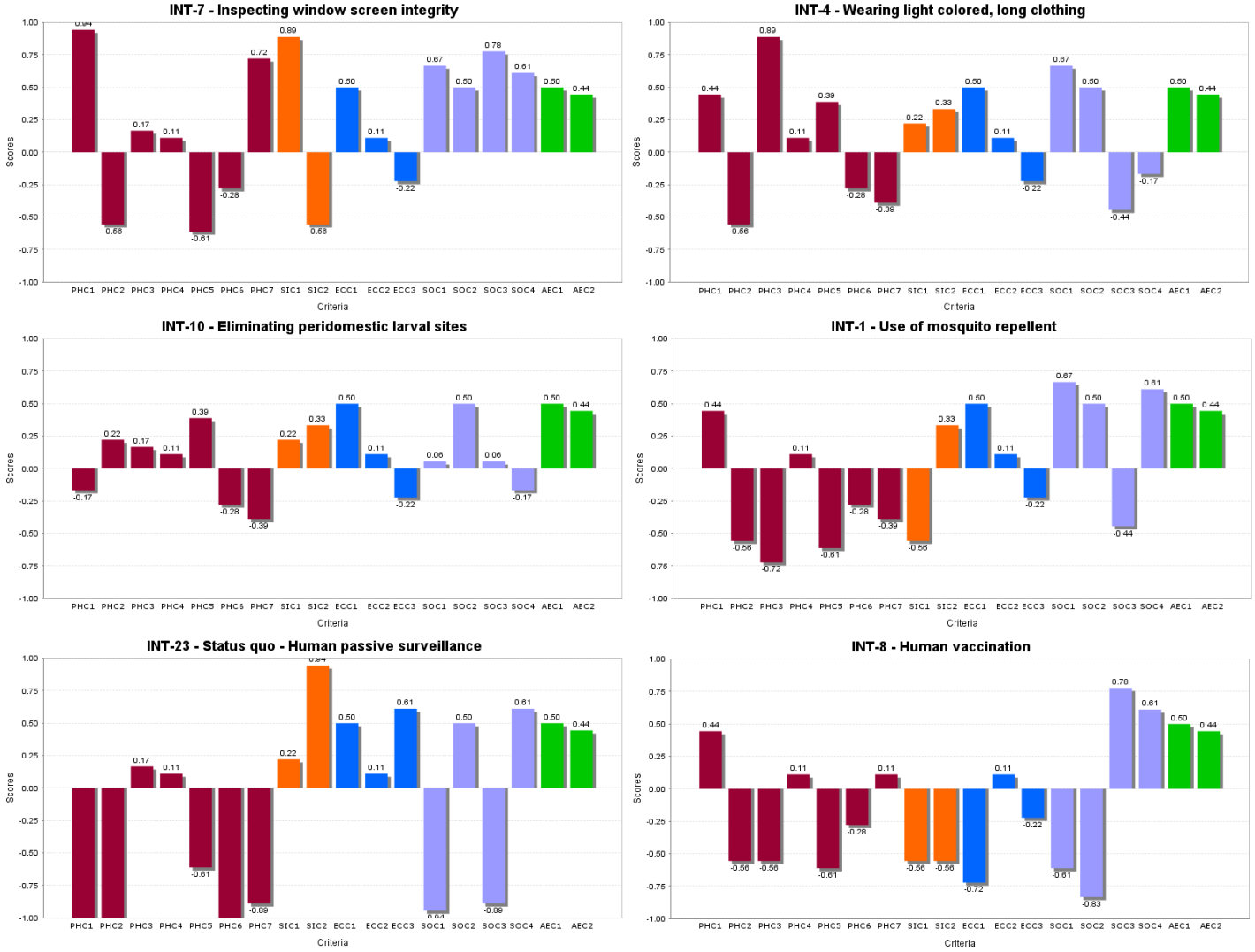


Figure 5. Intervention profiles for six individual-level protection interventions.

Ranking of regional-level interventions for Quebec

In the model containing regional-level management interventions (Table 12), the top three interventions were consistently: *larvicides*, *vaccination of animal reservoir* and *modification of man-made larval sites* with small variations in the order of these interventions depending on the scenarios. Examination of regional-level intervention profiles showed *larvicides*, *vaccination of animal reservoir* and *modification of man-made larval sites,* to be top scorers over most of the criteria, although *Larvicides*

scored less well on the "government cost", "complexity", "other policy impact", "animal health impact" and "environmental impact" criteria (see Appendix 2). The *vaccination of animal reservoir* intervention was found to score less well on the "incidence reduction" criterion compared to *larvicides*, but scored relatively well on other criteria "reduction of circulating virus" criterion in particular. The *modification of man-made larval sites* intervention scored less well on "Economic" criteria, "Strategic and Operational" criteria and the "Animal and Environmental Health" criteria.

Table 12. Ranking of the regional-level management interventions for QC.

Scenarios	Low risk				Medium risk				High risk			
	1		2		3		4		5		6	
Intervention	Rank	Net Flow	Rank	Net Flow	Rank	Net Flow	Rank	Net Flow	Rank	Net Flow	Rank	Net Flow
INT-08 Human vaccination	10	-0.18	8	-0.13	8	-0.17	9	-0.21	7	-0.13	7	-0.15
INT-11 Modification of natural larval sites	5	0.01	6	-0.01	4	0.12	4	0.17	4	0.13	4	0.13
INT-12 Modification of man-made larval sites	3	0.10	3	0.08	3	0.18	3	0.18	2	0.22	2	0.21
INT-13 Use of parasites and pathogenic micro-organisms	7	-0.07	7	-0.07	7	-0.13	7	-0.13	8	-0.16	8	-0.15
INT-14 larvicides	1	0.21	2	0.19	1	0.25	1	0.28	1	0.29	1	0.27
INT-15 Use of mosquito predators	4	0.09	4	0.05	5	0	5	0.02	5	0.02	5	0.01
INT-16 Dissemination of sterile males	8	-0.15	9	-0.16	9	-0.19	10	-0.21	10	-0.21	9	-0.21
INT-17 Use of adulticides	9	-0.17	10	-0.22	10	-0.21	8	-0.19	9	-0.19	10	-0.21
INT-18 Vaccination of animal reservoir	2	0.20	1	0.24	2	0.22	2	0.19	3	0.15	3	0.19
INT-23 Status quo – Human passive surveillance	6	-0.05	5	0.02	6	-0.07	6	-0.10	6	-0.12	6	-0.1

The ordering of the bottom three interventions included: *use of adulticides*, *dissemination of sterile males*, and *human vaccination* in the low and medium-risk scenarios. For the high-risk scenarios, the bottom ranked interventions changed to include *use of parasites and pathogenic microorganisms* instead of *human vaccination*.

Ranking of combined individual- and regional-level interventions for Quebec

In the combined model of individual- and regional-level interventions (Table 13), *inspecting window screens* and *wearing lightly colored clothing* were always ranked 1st and 2nd. This was most often followed by *larvicides* in all but the low-risk scenario 2 where it was replaced by *eliminating peridomestic larval sites*. The bottom three ranked interventions most often included *use of parasites and pathogenic microorganisms*, *dissemination of sterile males*, and *adulticides*.

Table 13. Ranking of combined individual-level and regional-level management interventions for QC

Scenarios	Low risk				Medium risk				High risk			
	1		2		3		4		5		6	
Intervention	Rank	Net Flow	Rank	Net Flow	Rank	Net Flow	Rank	Net Flow	Rank	Net Flow	Rank	Net Flow
INT-01 Use of mosquito repellent	9	0.00	7	0.06	9	0.05	10	0.02	10	0.02	10	0.02

INT-02 Use of domestic insecticides	11	-0.04	9	0.02	11	0.01	11	-0.02	12	-0.06	11	-0.04
INT-03 Use of alternative technologies	14	-0.11	12	-0.04	12	-0.05	12	-0.07	14	-0.12	14	-0.09
INT-04 Wearing light colored, long clothing	2	0.19	2	0.22	2	0.27	2	0.25	2	0.27	2	0.25
INT-05 Reduction of activities at peak times	5	0.11	4	0.13	4	0.14	5	0.12	4	0.13	5	0.11
INT-06 Reinforcing the immune system	13	-0.06	10	-0.02	13	-0.07	14	-0.08	11	-0.06	12	-0.06
INT-07 Inspecting window screen integrity	1	0.32	1	0.34	1	0.34	1	0.33	1	0.35	1	0.33
INT-08 Human vaccination	17	-0.15	16	-0.15	16	-0.19	17	-0.21	15	-0.14	15	-0.16
INT-09 Wearing insecticide treated clothing	10	-0.02	8	0.03	8	0.05	9	0.07	8	0.05	9	0.03
INT-10 Eliminating peridomestic larval sites	6	0.11	3	0.14	5	0.14	4	0.12	6	0.11	4	0.12
INT-20 Modification of natural larval sites	12	-0.06	15	-0.10	10	0.02	8	0.07	9	0.05	8	0.05
INT-21 Modification of man-made larval sites	7	0.01	11	-0.04	7	0.05	7	0.07	5	0.12	6	0.11
INT-22 Use of parasites and pathogenic micro-organisms	15	-0.12	17	-0.16	17	-0.21	16	-0.19	17	-0.22	17	-0.21
INT-23 Larvicides	3	0.16	6	0.10	3	0.14	3	0.18	3	0.20	3	0.18
INT-24 Use of mosquito predators	8	0.01	13	-0.07	14	-0.11	13	-0.08	13	-0.07	13	-0.07
INT-25 Dissemination of sterile males	18	-0.16	18	-0.22	18	-0.25	18	-0.24	19	-0.26	18	-0.25
INT-27 Use of adulticides	19	-0.19	19	-0.26	19	-0.28	19	-0.25	18	-0.24	19	-0.25
INT-28 Vaccination of animal reservoir	4	0.13	5	0.11	6	0.09	6	0.08	7	0.06	7	0.09
INT-32 Status quo - human passive surveillance	16	-0.12	14	-0.08	15	-0.15	15	-0.17	16	-0.19	16	-0.17

Malaria in Burkina Faso

Twelve stakeholders participated in the consultations and discussions around malaria management in Burkina Faso. Following discussion with stakeholders, 34 interventions (Table 14) and 20 evaluation criteria were retained (Table 15). In similarity to the West Nile virus model, interventions included individual protective measures, mosquito source reduction measures, and adult mosquito control measures.

The evaluations of interventions were once again aggregated with criteria weights and analyzed using a multi-criteria analysis tool. Here only regional level interventions were assessed. In contrast with the Quebec model, far less congruence was observed among weights expressed by Burkina Faso stakeholders. Instead, a large amount of variability was observed, indicating highly differing views and perspectives among stakeholders participating in this instance of the exercise.

Table 14. Interventions for the management of malaria in BF.

Individual-level interventions		
Code	**Interventions**	**Description**
INT-I1	Use of mosquito repellent	Ex.: containing DEET, p-menthane-3,8-diol applied to skin
INT-I2	Use of domestic insecticides	Ex.: aerosols, torches, mosquito coils, etc.
INT-I3	Use of alternative technologies	Ex.: automatic insecticide dispensers, electric traps, etc.
INT-I6	Reinforcing the immune system	Education and balanced nutrition to enhance immune system
INT-I7	Use and inspection of window screens	Install and inspect integrity of screens on windows and doors
INT-I8	Human vaccination	Alternative in development
INT-I9	Wearing insecticide treated clothing	Insecticide treated clothing (Permethrin treated)
INT-I10	Sleeping under an insecticide treated bed net	Use of deltamethrin or Permethrin treated bed nets
INT- I11	Use of alternative mosquito repellents	Ex.: Neem creams, FASO soap, etc.
INT- I12	Use of traditional plants to repel mosquitoes	Ex.: drinking specific teas to help repel plants
INT- I13	Use of air conditioners or fans	
INT- I14	Use of anti-malarial medication	Chemoprophylaxis
INT- I15	Home treatment with traditional plants	
INT- I16	Home treatment with pharmacy bought medication	
INT- I17	Private indoor residual spraying	
INT- I18	Improving sanitation of domestic habitats	Including the eliminating peridomestic larval sites
Regional-level interventions		
Code	**Interventions**	**Description**
INT-R1	Modification of larval sites (both natural and artificial)	Ex.: water banks, swamps, marshes,
INT-R2	Larval control of aquatic habitats	Ex.: BTI or insecticides
INT-R3	Indoor residual spraying	
INT-R4	Use of genetically modified mosquitoes	
INT-R5	Outreach and awareness campaign and free bed net distribution	Deltamethrin or Permethrin treated nets
INT-R6	Human vaccination	Alternative in development
INT-R7	Use of rapid diagnostic tests and artemisinin based therapies	
INT-R8	Reinforce health agent skills and competencies	
INT-R9	Targeted intermittent treatment for vulnerable groups	Ex.: pregnant women and children under 5
INT-R10	Seasonal chemoprophylaxis for children 3-59 months	
INT-R11	Promotion, support and valorisation of research results	
INT-R12	Promotion, support and valorisation of traditional medicine	
INT-R13	Protection of the environment and traditional plants	
INT-R14	Training and tools with community volunteers to ensure awareness and treatment with TDR	
INT-R15	Strengthening collaborative links and integration with nutrition programs and other diseases	
INT-R16	Development of inter-sectoral collaboration	

Table 15. Criteria for the management of malaria in Burkina Faso.

Category	WNV criteria	Description
Public Health Criteria (PHC)		
	PHC1 - Incidence reduction	Reduction in incidence of human cases
	PHC2 - Entomological risk reduction	Reduction of entomological risk
	PHC3 –Physical health impact	Impacts to human physical health
	PHC4 - Mental health impact	Impacts to human mental health
	PHC5 – Social equity*	Impact on social equity
	PHC7 – Proportion affected	Proportion of population that benefits from the action
	PHC8 – Appropriate differential diagnostic	Adds to correct differential diagnostic between malaria and other diseases with similar symptoms
Social Impact Criteria (SIC)		
	SIC1 – Public acceptance	Level of public acceptance
	SIC2 – Impact to credibility	Impact to confidence in and credibility of organisation in charge
	SIC3 – Public awareness	Level of public awareness and sensitization to the disease
Economic Criteria (ECC)		
	ECC1 – Government cost	Cost to the government
	ECC3 – Individual cost	Cost to individuals
	ECC4 – Private cost	Cost to private sector and NGOs
Strategic & Operational Criteria (SOC)		
	SOC1 - Delay	Delay before appearance of desired effect
	SOC2 – Complexity	Institutional and operational complexity of the action
	SOC3 – Sustainability *	Sustainability of the action
	SOC4 – Other policy impact*	Impact on other public policies
	SOC5 – Optimization opportunities	Opportunities for optimization with other vector control interventions or other health related programs
Animal & Environmental Criteria (AEC)		
	AEC1 – Animal health impact	Impact on animal health
	AEC2 – Environmental impact	

* Criteria added following discussion with stakeholders

Note: Criteria are listed in “quotes” when referenced in the text to distinguish from *interventions* which are listed in *italics*

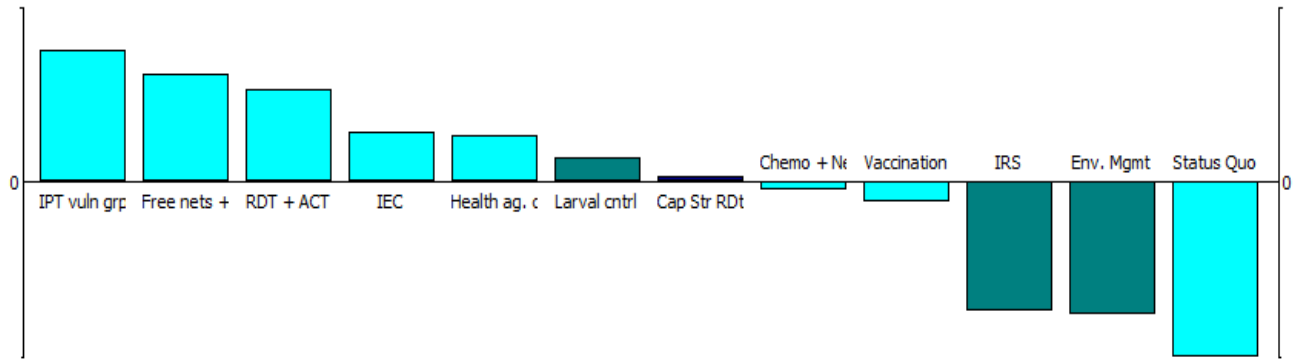


Figure 6. Regional-level management intervention ranking for BF

Weights tended to vary considerably between stakeholders as observed in Table 16. The weight ranking of categories for this region was public health, operational, economic, social impact and animal health respectively in that order.

Table 16. Criteria weights by stakeholders

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
PHC-01	5	20	2	7.5	3.2	5	7	2	15	11
PHC-02	3	0	2	5	10	5	6	0.3	7	0
PHC-03	1	8	6	2.5	3.2	3.75	10	5	9	0
PHC-04	2	2	0.5	1.25	14.8	1.875	8	0.4	0	6
PHC-05	2	4	0.5	1.25	1.2	1.875	3	0.7	0	6
PHC-06	3	2	1	1.25	1.2	3.75	4	0.1	0	6
PHC-07	4	4	3	6.25	6.4	3.75	7	1.5	7	6
SIC-01	10	18	2	1	6.5	8	5	12	8	7
SIC-02	5	3	4	2	2.75	4	3	5	3	0
SIC-03	5	9	4	7	15.75	8	2	5	5	7
AEC-01	5	1	3	3	3.5	5	4	2	4	6
AEC-02	15	9	2	12	3.5	5	6	6	8	6
ECC-01	5	2	10	5	10.8	7.5	7	15	2	0
ECC-02	5	1.5	5	7	3.2	5	4	9	6	7
ECC-03	10	1	5	7	4.4	7.5	3	4.5	6	7
ECC-04	0	0.5	5	1	1.6	5	1	1.5	3	0
SOC-01	2	4.5	2	12	1.2	5	5	12	5	10
SOC-02	3	3	14	7.5	1.04	4	4	9	5	5
SOC-03	10	4.5	25	6	2.32	6	6	6	4	5
SOC-04	5	3	4	4.5	3.44	5	5	3	3	5

Intervention rankings for Burkina Faso

In the regional-level management interventions model (Table 17, Fig 6), the top three identified interventions included: IPT to vulnerable groups, distribution of free bed nets, and rapid diagnostic tests and ACTs.

Table 17. Ranking of the regional-level management interventions for BF.

Intervention	Rank	Net Flow
INT-N1 Information and education campaign (e.g. bed nets)	4	0.021
INT-N2 Strengthen health agent capacity	7	0.003
INT-N3 IPT vulnerable groups	1	0.303
INT-N4 Distribution of free bed nets and sensitization campaign	2	0.260
INT-N5 Mass vaccination campaign	9	-0.045
INT-N6 RDT + ACTs	3	0.078
INT-N7 Chemoprophylaxis children under 5	8	-0.030
INT-N8 Targeted Larval control	6	0.016
INT-N9 Indoor residual spraying	10	-0.146
INT-N10 Environmental management	11	-0.152
INT-N11 Capacity strengthening of CRAs	5	0.019
INT-23 Status quo	12	-0.228

Lyme disease in Manitoba

As part of a fall back plan, a validation exercise was carried out in Manitoba to assess adaptability of a previously constructed Lyme disease model from Quebec. These results are presented in the following section.

Stakeholders

A stakeholder consultation was held on January 22nd, 2015 in the city of Winnipeg, Manitoba at Manitoba Health, Healthy Living and Seniors. Invitations to attend the session were sent by collaborators at Manitoba Health, Healthy Living and Seniors to contacts with interests in zoonotic disease management. A total of 9 stakeholders attended the discussion session from the following organisations: Manitoba Health, Healthy Living and Seniors, Saskatchewan Ministry of Health, Zoonotic diseases consultant, Manitoba Government, veterinary public health, City of Winnipeg, Public health agency of Canada, Independent researcher, University of Manitoba. This group of stakeholders included medical doctors, veterinarians, and entomologists.

Criteria and weights

The original Quebec (QC) Lyme disease model (71) was presented and discussions were held regarding the necessary modifications for its application in MB. This same model was used as a starting point for the creation of the mosquito-borne disease models described in earlier sections and as such criteria and categories of interventions are similar. Following discussion with stakeholders, the original 12 criteria from the Quebec model were retained and 9 new criteria were added for a total of 21 criteria distributed among 5 criteria categories: public health, social impact, animal and environmental health, economic and strategic and operational impact criteria. Many of the newly suggested criteria were similar to the proposals made in Switzerland. Strategic and operational criteria were separated from economic criteria in the Manitoba model. A detailed list of the criteria used in the models, the direction of the desired effect and scale, is included in the appendix. The new criteria that were added for Manitoba were the following:

In the public health category:
- Reduction of disseminated Lyme cases
- Increased case detection

In the social impact category:
- Increased public awareness

In the Animal and environmental health category:
- Reduction in incidence of animal cases

In the economic criteria category:
- Savings to the public sector
- Potential benefits to the private sector

In the strategic and operational impact category:
- Sustainability of effect
- Intra-regional coherence
- Inter-regional coherence

Stakeholders were asked to weight retained criteria in the model according to the two described transmission scenarios. The details of the weightings made by all nine stakeholders (S1-S9) for each of the two hypothetical transmission scenarios are shown in tables 18 and 19.

Table 18. Low incidence scenario weightings by stakeholder (S1-S9) for all criteria.

		S1	S2	S3	S4	S5	S6	S7	S8	S9
Public Health criteria	PHC-01	14	14	10	10	10	11	6	16	10
	PHC-02	8	5.3	4	9	10	6	4.5	2	2
	PHC-03	14	5.3	10	4	8	8	6	6	5
	PHC-04	14	3.5	6	4	8	8	4.5	4	10
	PHC-05	6	7	5	6	4	2	9	12	6
Social impact criteria	SIC-01	2	4.5	4	10	6	8	4.5	2	5
	SIC-02	3	4.5	7	2	1.5	12	3.8	8	8
	SIC-03	8	6	7	9	2.5	10	6.8	10	5
Animal and environmental health criteria	AEC-01	4	3.8	5	10	6	4	7.5	13	4
	AEC-02	4	3.8	5	4	7	5	10	10	4
	AEC-03	0	7.5	5	4	7	3	7.5	2.5	2
Economic Criteria	ECC-01	4	4.5	3	2	10	2	2.5	3	4
	ECC-02	1	3	2	1	4	4	1.5	0.5	4
	ECC-03	2	4.5	3	3	4	2	3.5	1	5
	ECC-04	1	3	2	2	2	3	2.5	0.5	5
Strategic and operational impact criteria	SOC-01	2	2	4	2	1	2	1	1	2
	SOC-02	4	2	3	4	1	2.5	3	1	3
	SOC-03	4	6	3	3	4	2.5	3	2	4
	SOC-04	3	2	5	6	2	2.5	6	4	6
	SOC-05	1	2	3	1	1	1	5	1	1
	SOC-06	1	6	4	4	1	1.5	2	1	5

Table 19. High incidence scenario weightings by stakeholder (S1-S9) for all criteria.

		S1	S2	S3	S4	S5	S6	S7	S8	S9
Public Health criteria	PHC-01	16	16	10	12	25	11	11	20	20
	PHC-02	8	6	2	10	7.5	6	4.5	2	1
	PHC-03	17	6	8	2	6	8	3	8	5
	PHC-04	17	4	10	4	6	8	3	4	10
	PHC-05	6	8	8	1	6	2	9	6	12
Social impact criteria	SIC-01	2	4	5	10	3.6	4	6	2	5
	SIC-02	3	6	6	1	3.6	20	6	4	10
	SIC-03	8	10	8	12	1.8	6	3	14	12
Animal and environmental health criteria	AEC-01	3	6	3	10	4.5	5	6	13	2
	AEC-02	3	2	3	4	5.3	4	4	11	2
	AEC-03	0	2	3	4	5.3	3	10	1.3	1
Economic Criteria	ECC-01	4	3	1	2	5.2	2	5.3	4	2
	ECC-02	0	2	1	1	2	4	1.5	1	1
	ECC-03	3	3	1	2	5.2	2	4.5	4	1
	ECC-04	0	2	1	1	0.7	3	3.8	1	1
Strategic and operational impact criteria	SOC-01	1	6	8	5	1.3	1.5	7	0.5	3
	SOC-02	3	2	4	5	1.3	2.5	2	0.3	2
	SOC-03	3	6	5	3	5.2	2.5	4	2.5	3
	SOC-04	2	2	6	5	2.6	2.5	3	1	5
	SOC-05	0	2	1	1	1.3	1.5	3	0.5	1
	SOC-06	1	2	6	5	1.3	1.5	1	0.3	1

Without exception, all stakeholders gave more weight to the Public Health criteria category than all other categories under both scenarios. In general, stakeholders gave higher weight to the public health criteria category at the expense of other categories under the high incidence scenario with the exception of stakeholder S4 that gave less weight to this category under this scenario and stakeholders S6, S7 and S8 all of whom gave the same weight to this category under both scenarios. Although stakeholders S4, S6, S7 and S8 gave the same or less to the public health criteria category under scenario 2, generally more weight was given to criteria PHC-01 (reduction of human cases of Lyme disease) under scenario 2 for all of these stakeholders with the exception of stakeholder S6 who gave the same weight to criteria in this category under both scenarios 1 and 2.

Interventions

The list of sixteen interventions originally included in the Quebec model was presented to stakeholders. These action represented potential prevention and control actions that could be currently or eventually put into place to help manage Lyme disease in Quebec. Following discussion with stakeholders in Manitoba, the original list of sixteen actions was retained and 7 new actions were added to the model for a total of 23 actions. These new actions suggested by stakeholders in Manitoba could be categorized as interventions targeting humans, vectors in the environment and vectors on reservoir hosts. The new actions that were added for Manitoba were the following:

- Discourage access to high-risk public areas (via warning signs warning)
- Large scale communication campaign
- Increase physician awareness and knowledge
- Controlled fires separated as distinct action from general large scale landscaping
- Targeted rodent control
- Rodent vaccination
- Status quo MB

Status quo baseline interventions for Quebec and Manitoba were both included in the Manitoba model even though these two actions differed as a result of the differences in baseline public health effort in the two provinces. Status quo in Quebec at the time of the original model creation was defined as basic preventive health messages made available to the public via the provincial health authority website. Status quo in Manitoba for the purposes of the current project has been defined as basic preventive health messages with public outreach including informational stands at outdoor events, garden centers and recreational camps. A detailed list of all interventions used in both the Quebec and Manitoba models is shown in table 21.

It was suggested that ALT-01: Excluding people from high-risk public areas be removed from the Manitoba model given that the action was deemed to not be applicable in Manitoba based on discussion with stakeholders; however, during follow-up surveys asking stakeholders which actions should be retained in the model, an argument was made to keep it in the model for comparison sake.

Table 20. Interventions included in the models

	MB Model			QC Model	
	Code	Action	Description	Code	QC description
Human targeted strategies	ALT-1	Excluding people from high-risk public areas	Restrict access of the general public to high-risk tick areas e.g. parks	CONT10	
	ALT-2*	Discourage access to high-risk public areas	Install warning signs concerning Lyme disease risk in designated Lyme risk areas in order to inform the general public	N/A	N/A
	ALT-3	Human vaccination	Alternative not currently available but exists	CONT11	Human vaccination
	ALT-4	Setup special Lyme disease diagnostic/treatment clinics	Setup specialized diagnostic and treatment clinics to increase public sensitization to the issue and help reduce the number of cases by improving detection and treatment of the disease	CONT12	Making available special Lyme disease diagnostic/treatment clinics
	ALT-5*	Large scale Lyme disease communication campaign	Widespread educational campaign promoting main methods of Lyme disease prevention (including use of tick repellent)	N/A	N/A
	ALT-6*	Increase physician awareness and knowledge of Lyme disease	Promote physician knowledge and active lookout for Lyme disease cases via informational newsletters and training courses	N/A	N/A
Vector targeted environ-mental strategies	ALT-7	Small scale landscaping (removal of tick habitat)	Removal of tick and deer favourable habitat at small scale via various methods e.g.: mowing, removal of leaves, bush and tree removal	CONT3a	Small scale landscaping (removal of tick habitats)
	ALT-8	Large scale habitat modification (removal of tick habitat)	Removal of tick and deer favourable habitat at large scales via various methods e.g.: mowing, removal of leaves, bush and tree removal	CONT3b	Large scale landscaping (removal of tick habitats)
	ALT-9	Small scale acaricide application to kill free-living ticks on public grounds	Application of granular Acaricides or aerosols to kill free living ticks in the environment at small scales (e.g. organophosphates, carbamates, pyrethroids)	CONT1a	Small scale acaricide application to kill free-living ticks
	ALT-10	Large scale acaricide application to kill free-living ticks	Application of granular Acaricides or aerosols to kill free living ticks in the environment at large scales (e.g. organophosphates, carbamates, pyrethroids)	CONT1b	Large scale acaricide application to kill free-living ticks
	ALT-11	Application of desiccants/insecticidal soap	Application of desiccants or insecticidal soaps to reduce tick density in the environment (pyrethroid containing). Less toxic than acaricides but require more frequent application	CONT2	Application of desiccants/insecticidal soap
	ALT-12*	Controlled fires	Removal of tick and deer favourable habitat via controlled burn	N/A	N/A

Host intervention strategies	ALT-13	'4-poster' device	Cutaneous application of Acaricides to deer via food (corn) distribution devices	CONT4	'4-poster' device
	ALT-14	Feed-administered ivermectin to deer at bait stations to control ticks	Oral treatment of deer using bait stations containing ivermectin treated corn	CONT5	Feed-administered ivermectin to deer at bait stations to control ticks
	ALT-15	'Damminix' device	Installation of cardboard tubes containing Permethrin treated cotton useable by rodents for nesting	CONT8	'Damminix' device
	ALT-16	Bait boxes to deliver a passive application of fipronil to rodents	Topical insecticide method to treat rodents with fipronil	CONT9	Bait boxes to deliver a passive application of fipronil to rodents
	ALT-17*	Targeted rodent control	Rodent eradication in controlled areas such as farms, etc.	N/A	N/A
	ALT-18*	Rodent vaccination	Rodent targeted bait vaccine to reduce *B. Burgdorferi* infection	N/A	N/A
	ALT-19	Exclusion of deer by fencing	Restriction of deer access to certain areas via gates or fences in order to reduce tick populations	CONT7	Exclusion of deer by fencing
	ALT-20	Deer hunting	Reduction of deer population via controlled hunt to reduce tick populations (several years' delay)	CONT6a	Deer hunting
	ALT-21	Deer culling	Reduction of deer population via deer cull to reduce tick populations (several years' delay)	CONT6b	Deer culling
Status quo	ALT-22	Status quo – QC	Continue with current course of passive Lyme prevention and control communication on website, no new action	CONT0	Status quo (basic preventive communication strategy)
	ALT-23*	Status quo – MB	Continue with current course of active Lyme communication outreach actions (community events, garden centers, camps, etc...)	N/A	N/A

*** New actions added in the Manitoba model**

In addition to the new evaluations required for newly added actions and criteria, modifications were also made to existing evaluations in order to align them with the current Manitoba Lyme disease transmission and management context. The details of these modifications are listed in the appendix.

6. Analysis and discussion

Disease prioritization

Criteria and Context

In examining the results of the disease prioritization exercise carried out in Quebec and Burkina Faso, a number of similarities and differences between retained criteria can be observed. The presence of consistent criteria, such as the severity of a disease and risk perception, suggests that similar concerns may apply across regions when prioritizing resources to reduce the public health impact of diseases. Some of these potentially generalizable dimensions have been seen in previous studies with the most common categories pertaining to minimizing the burden on the population, accounting for the existing health system capacity and feasibility of management (76). In the current study, in addition to the criteria common to both regions, a number of modifications were made by stakeholders in each region in order to clarify and add relevance pertaining to the decision context of the region. These adjustments reveal important details with respect to resource availability, capacity and concerns that should be taken into account when discussing and planning prioritization of infectious diseases.

It should be noted that the focus group discussion with stakeholders in BF took place in the midst of the Ebola outbreak that was ongoing in the West African region (2015). Although no cases of Ebola were reported in BF, the threat and fear of the disease was at the forefront of the minds of all. The effect of the neighboring Ebola crisis likely had a significant impact on the criteria discussed by stakeholders in BF as illustrated by the BF specific criteria added by stakeholders. These included criteria pertaining to the disease being “new” for the region, risk perception by various groups as well as criteria pertaining to access to treatment and conditions for treatment. The risk perception criteria in particular capture the concern expressed by stakeholders as to the important potential differences between the level of threat perceived by health workers, decision makers and the international community. Moreover, access to treatment and availability of adequate conditions to treat a disease are part of the reality of the health management context in BF, but were also brought up as a direct response to what was observed in neighboring countries during the Ebola crisis such as limited availability of potential vaccines to treat the disease and access only to select patients at the time.

Criteria weighting

The large weight span range among stakeholders in BF compared with QC stakeholders suggests stronger consensus or alignment of values among this later group of stakeholders even if individuals came from different sectors. The focus group discussion in QC was coherent with a potential categorical separation between economic concerns and more feasibility related concerns as found within the strategic and operational considerations category; however, during the focus group discussion in BF, all feasibility concerns were first and foremost related to economic concerns. “Economic” concerns such as the instability of funds were a topic that was brought up repeatedly throughout the course of the discussion. Lack of autonomy with regards to funding decisions can be crippling and frustration could be heard from stakeholders during discussion regarding the inability of researchers to select their own research topics due to financial priorities imposed by foreign investors. The finding of “Strategic and Operational” concerns being generally weighted above “Public Health” concerns (with an even greater discrepancy between these relative rankings if “Economic” and “Strategic” criteria were combined into

one same category), reflects the overriding economic discourse that appears to drive much decision making in the region. Burton previously noted that "(high income countries) have generally assumed that they have the financial and technical resources to adapt as and when necessary" (77) suggesting that operational considerations are rarely the primary obstacles in decision making which is in marked contrast to discussions held with local stakeholders in BF.

The narrowest weight span was found for the "Animal and Environmental Health" category in BF suggesting stronger consensus among stakeholders as to the reduced importance of this category for them relative to all other categories. While the "Animal and Environmental Health" category was also among the bottom three weighted categories in QC, there was more dispersion in the weights given to this category suggesting that there was less of a consensus as to the relative importance of this category for QC stakeholders.

Effect on disease prioritization

Burkina Faso (BF) and the province of Quebec (QC) are very different regions on a multitude of levels. Notably, with regards to mortality, the leading cause of which is infectious diseases in BF whereas in QC, the greatest burden of disease across all ages is primarily due to non-communicable diseases.
Based on the weights expressed by stakeholders, and region specific data assessments of the pilot diseases, some differences were found between the two regions in the ranked importance of these diseases.

In QC, the only disease currently occurring endemically is WNV and likely explains its first place ranking for this region. Among the remaining disease, while *MAL* and *DENV* may be similarly of concern with regards to health severity, the current existence of suitable vectors for *MAL* in QC likely explains its higher ranking over *DENV* for this region. Suitable vectors (*Aedes albopictus* and *Aedes aegypti)* for *CHIKV* and *DENV* exist in the United States (78) but are not yet present in Canada. There are concerns of these vectors making their way to Canada with continued climate change (79). *Malaria* has historical transmission in Canada and the US prior to eradication efforts in the early 20th C and therefore suitable transmission conditions exist (i.e. vector and climate); however, studies examining chances of autochthonous transmission of this disease in Canada estimate that the risk is low given the disease transmission cycle requirements of this parasitic disease and current healthcare system (80). While the combination of factors required for emergence and transmission of diseases is complex, the chances of a viral disease outbreak are generally considered to be higher once suitable vectors become present as replication times and requirements are generally shorter and simpler than for parasitic diseases (81). Recent viral outbreaks in the United Kingdom would appear to support this (82). *CHIKV* and *LF* have lower health severity and once again, the existence of effective treatment for *LF* is likely a driving cause of its last place ranking (hence lower concern).

In BF, *DENV* was ranked first among the five diseases according to the group ranking followed by *MAL, CHIKV, LF and WNV respectively.* The assessments for *DENV* and *MAL* differed primarily on the following criteria: "current incidence of human cases in the country" (currently unknown in the case of *DENV),* public perception and knowledge (relatively lower for *DENV* than for *MAL* currently in BF*),* "current global trend of disease over last 5 years" (*MAL* has been generally stable in the region),incidence and severity of animal disease (not applicable to *MAL),* cost to government and NGOs (more investment currently made for *MAL* hence costs higher), detection and treatment (treatment exists for *MAL* though a potential *DENV* vaccine may soon become available (83)). Furthermore, stakeholder weighting of criteria likely played an important role in the final group ranking of *DENV* above *MAL. DENV* outbreaks have occurred in BF (most recently in 2013 (84)) but current exact

incidence and prevalence numbers are incomplete. Although *MAL* is the leading cause of death among infectious diseases in BF, there is growing concern about underreporting and detection of *DENV* and greater attention to this disease is warranted (84). While *CHIKV* may be present in BF, its lesser health severity compared with *DENV* and *malaria* likely play the largest part in reducing its priority order for this region. *LF* has long been present in the region, but also has lower health severity and effective treatment available. *WNV* has lower health severity assessment compared to the other four diseases and is likely the primary reason for its last place ranking.

Limitations

The list of criteria identified and validated with stakeholders was based on an initial review of the literature by the authors and would likely have differed if criteria had been solely identified by stakeholders. However, in the interest of working towards a "complete" list of criteria, the participatory approach with stakeholders following the creation of an initial literature based set, allowed stakeholders to complete and give their opinion on criteria that have been used elsewhere resulting in an arguably more complete list than would have otherwise been created.

The weighting exercise may have been challenging for some stakeholders while fairly intuitive for others. Given this, alternative weight elicitation methods may be worth pursuing depending on the context and experience of stakeholders. Alternative approaches used elsewhere include discrete choice experiment approaches (57) such as conjoint analysis (85) and consensus methods. The pilot prioritization exercise was aimed at illustrating the effect of different criteria and weights on disease ranking and should not be interpreted as a formal assessment of local priorities. Data from the literature and from discussions with stakeholders was used to score diseases. Additional data and further discussions with experts are warranted to verify the validity of these findings.

Intervention prioritization

West Nile virus in Quebec

In examining the results of the intervention prioritization exercise for West Nile virus management in Quebec, we demonstrated the potential for adaptation planning of WNV under climate change transmission scenarios using multi-criteria decision analysis (MCDA). The categories retained in our study are consistent with previous multi-stakeholders concerted decisions that have taken place in public health over the past 20 years (73,86,87). Aenishaenslin and colleagues (2013) had previously demonstrated the possibility of MCDA use for management of Lyme disease emergence in Canada and had suggested that general criteria categories exist that are suitable for VBZD management at large (71). Our study further supports the application of MCDA for VBZD and reinforces the notion of common categories of concern to consider in VBZD management. Additionally, our study has shown how many of these concerns remain relevant under various scenarios of transmission intensity with climate change.

The degree of concern (weights) attributed to different criteria by stakeholders was shown to vary with transmission intensity of scenarios. This was expected as we anticipated that an increasing number of reported cases in the scenarios would lead to increased concern for public health and social impact related considerations thereby triggering a trade-off among remaining criteria. A similar result was found in the Lyme disease study (71). The ranking of interventions was found to vary under different scenarios and among the different models. This was also expected since changes in weights affect rankings. Intervention profiles can be examined to further understand the relative rankings of interventions independently of stakeholder assigned weights (see supplementary material for

comprehensive coverage of profiles). Model rankings and interpretation are discussed in more detail in the following sections.

The relative rankings of individual-level interventions were generally not found to vary considerably across the scenarios (low to higher risk transmission). This stability suggests specific protective behaviors that remain effective and acceptable and should continue to be promoted in communication campaigns in order to reinforce adaptive capacity to climate change. The individual-level model results observed where *inspection of window screens, wearing light colored clothing, eliminating peridomestic larval sites* and *reducing outdoor activities at peak times* were highly ranked and *use of alternate technologies, human vaccination* and *status quo* were lower ranked are consistent with primary prevention messages already included in Quebec WNV communication campaigns as well as other Canadian and the US ones (88–90). These messages are also consistent with personal protection methods prescribed within integrated vector management programs in Europe (91). The *inspection of window screens* in particular was the most highly ranked intervention at this level and indeed is already a common and well accepted practice in most homes in the province of Quebec (92). As such few if any financial costs are expected to be associated with the promotion of this strategy; however, individuals without sufficient economic means may be less likely to replace or purchase window screens. Examination of the relative strengths and weaknesses of interventions via their intervention profiles illustrates how a comprehensive public health strategy can be built that addresses all concerns raised by stakeholders. For example, the second and third ranked interventions, *wearing light colored clothing* and *eliminating peridomestic larval sites,* which also ranked highly, are complementary to the *inspecting window screen integrity* intervention as they score well on criteria were *inspecting window screens* performed less well.

Overall, the rankings of regional-level interventions were found to vary more than individual-level interventions across the climate change transmission intensity scenarios. The positional stability of top ranked interventions here too suggests specific actions to manage WNV effectively that remain acceptable across a range of transmission dynamics. The positional change of other interventions such as *vaccination* or *modification of natural mosquito larval sites,* under the higher transmission risk scenarios suggests increased acceptability of potentially more controversial interventions under these conditions. Periodic re-evaluations are warranted as additional information becomes available for these interventions.

Evaluated regional-level interventions were primarily vector targeted with the exception of the *vaccination* (human and animal) and *status quo* (human passive surveillance) interventions. Top ranking interventions included *use of larvicides*, *vaccination of animal reservoir* and *modification of man-made larval sites* having scored highly on most criteria but with important trade-offs on other criteria. For example, *use of larvicides* scored poorly on cost, operational complexity and environmental criteria. Mosquito control programs are costly and complex to operate as they require entomological surveillance programs, well-trained staff and infrastructure (65) and repeated application in order to maintain effectiveness (93,94). Nevertheless, vector control remains key to effective vector borne disease management (95). While the *vaccination of animal reservoir* intervention was highly ranked, the inclusion of a criterion explicitly targeting the level of circulating virus in the animal reservoir may explain the high ranking of this strategy as it is the only measure that directly acts on this aspect of transmission. A few studies have demonstrated success with this measure (96–98) but for the time being, it remains a hypothetical intervention for the province of Quebec. With regards to *man-made larval sites, s*tudies have found that proximity to certain types of structures such as combined sewer overflow systems have been significantly associated with high rates of WNV infection in humans and

corvids; however, construction and modification of major infrastructure can be very costly (67,99,100). Additionally, man-made water systems such as those designed to handle sewer overflow may have negative impacts on water quality and animal health by association (101).

In the combined model, four out of the top seven interventions included individual measures. This suggests that based on available evidence, current epidemiological levels of WNV, and values held by experts in Quebec, interventions aimed at personal level protection, source reduction or reduction of circulating levels of virus are most appropriate over habitat modification interventions and other forms of vector control and also under the higher transmission risk scenarios described in this study. These results are in agreement with the management options currently implemented in Quebec and elsewhere in North America although other forms of vector control (such as the use of adulticides) have been employed elsewhere in North America under high levels of WNV transmission (64,102).

Limitations

From our initial stakeholder validated list, four interventions were found to currently lack sufficient data for evaluation (*use of lethal ovitraps*, *reduction in abundance of the main animal reservoir species*, *modification of habitat to reduce host reservoir species*, and *increasing biodiversity at the peridomestic level)*. While MCDA methods exist to deal with missing data (103), these were not explored in the current study to avoid speculating on their efficacy and acceptability. Future models should explore these interventions as data becomes available.

The exploration of multiple scenarios in the models did not yield very different rankings. Convergence of stakeholder values was seen under scenarios of increased transmission severity; however, this did not strongly impact rankings. Many of the stakeholders have been working together on WNV related projects for a number of years which may in part explain the observed homogeneity in responses. A recommendation for future studies would be to include a more diverse group of stakeholders to examine the potential variation in responses. Furthermore, to reduce workload, to explore low and high transmission scenarios first and if variations are found, to follow-up with medium transmission scenarios analyses where warranted.

Intervention evaluations were not re-assessed under the different scenarios. While many of these evaluations would likely not have changed, the social impact related evaluations might have with potential effects on rankings. However, no data were available to document this change for the current evaluation. An exploration of these and other potential changes to evaluations under different transmission scenarios in future studies may be warranted.

The PROMETHEE algorithm used in the ranking process provides a relative position for ordered interventions, therefore while general observations can be taken away from this analysis, such as individual preventive measures being preferred over regional-level interventions, the actual ranking results are valid only for the current model. In other words, middle or bottom ranked interventions should not necessarily be dismissed as being “poor”, rather they are less favoured over the top ranked interventions in the current model but still remain viable options to explore in future models or analyses as new options and information become available. Overall “poor” interventions, known to be so at the outset should not be included in the model in the first place. For this reason, it is worthwhile to explore specific subsets of interventions to further deepen our understanding of why one intervention may outperform another.

Malaria in Burkina Faso

In examining the results of the intervention prioritization exercise for malaria in Burkina Faso, we demonstrated how a process for participatory planning and management of a vector-borne disease, in this case, malaria, can be performed in a developing context using multi-criteria decision analysis (MCDA). Although highly influenced by the approach used where previously constructed models were presented, adapted and validated with stakeholders in Burkina Faso, the categories retained, were found to be similar with the models developed in other contexts.

Regional-level management model

The top ranked regional-level model results were fairly consistent with currently recommended WHO strategies to manage malaria including IPT for vulnerable groups, distribution of free bed nets, use of RDTs and ACTs and large scale information and education campaign on bed nets (104). Interestingly, indoor residual spraying (IRS) was ranked among the bottom three strategies. While IRS is among the WHO recommended strategies and a pilot project was carried out in Burkina Faso by USAID, this intervention has not been scaled up to the national scale in Burkina Faso due to insufficient funds to do so (105). Many of the ranked strategies are complementary and should be combined where possible to increase coverage efficacy. Examination of the individual action profiles can be done to improve combination of complementary interventions.

Limitations

Due to the validation nature of the malaria component of the project, a fully iterative MCDA process was not carried out. Instead, elements from the original Quebec model were used and adapted to fit the Burkina Faso context following discussions with a small group of stakeholders involved or interested in vector-borne disease management. As a result, the final list of included actions and criteria were influenced by and sensitive to the original Quebec parameters. Had a fully iterative process been carried out without reference to the original Quebec model, and with a different set of stakeholders, it is possible that important variations would have been obtained in the list of final actions and criteria retained for inclusion in the model. Furthermore, the evaluations of the actions over all criteria were contextualized for the Burkina Faso context based on consultation with only a small group of stakeholders. A fully iterative process and consultation with additional stakeholders and experts may have resulted in different evaluations of these parameters.

Lyme disease in Manitoba

The global ranking of all actions included in the model according to all stakeholders revealed the 5 most interesting actions for the group of stakeholders in the low transmission scenario were: ALT 5 (Large scale Lyme disease communication campaign), ALT-03 (Human vaccination), ALT-06 (Increase physician awareness and knowledge of Lyme disease), ALT-23(MB status quo) and ALT-02 (Discourage access to high-risk public areas) (Table 23). The 5 least interesting actions for the group of stakeholders were: ALT-19 (Exclusion of deer by fencing), ALT-15 (use of 'Damminix' devices), ALT-12 (Controlled fires), ALT-11 (Application of desiccants and insecticidal soap), and ALT-21 (Deer culling).

A graphical analysis of stakeholder positions relative to the group decision and evaluations of all actions showed that all stakeholders were generally in agreement with this final ordered ranking with no stakeholder in direct opposition to the final decision. Figure 7 shows a GAIA decision map of stakeholder positions relative to all actions with the decision axis shown as a bold red bar. This map shows that all stakeholders are generally in agreement with the group ranking since all stakeholders are positioned in the same direction as the final decision axis. Individual stakeholder analysis (Fig. 8) further revealed that

action ALT-5 (Large scale Lyme disease communication campaign) was the top preferred action for all stakeholders and was a dominant action among all other actions included in the model for the low transmission scenario.

Table 21. Rank and score of all potential actions according to all stakeholders for the low transmission scenario

Rank	action	Phi	Phi+	Phi-
1	ALT-05	0,4108	0,5370	0,1262
2	ALT-03	0,2293	0,4081	0,1788
3	ALT-06	0,1589	0,4699	0,3110
4	ALT-23	0,1565	0,4154	0,2589
5	ALT-02	0,1406	0,3567	0,2161
6	ALT-01	0,1110	0,3740	0,2631
7	ALT-04	0,0905	0,4207	0,3302
8	ALT-22	0,0686	0,3794	0,3108
9	ALT-13	0,0436	0,2849	0,2413
10	ALT-20	0,0191	0,2889	0,2698
11	ALT-09	0,0004	0,2771	0,2768
12	ALT-08	-0,0005	0,2781	0,2786
13	ALT-14	-0,0102	0,2618	0,2720
14	ALT-07	-0,0408	0,2635	0,3043
15	ALT-10	-0,0684	0,2487	0,3170
16	ALT-17	-0,1050	0,1933	0,2983
17	ALT-16	-0,1182	0,1911	0,3094
18	ALT-18	-0,1291	0,1789	0,3079
19	ALT-19	-0,1412	0,2292	0,3705
20	ALT-15	-0,1671	0,1662	0,3332
21	ALT-12	-0,1772	0,1704	0,3476
22	ALT-11	-0,2181	0,1544	0,3725
23	ALT-21	-0,2535	0,1407	0,3942

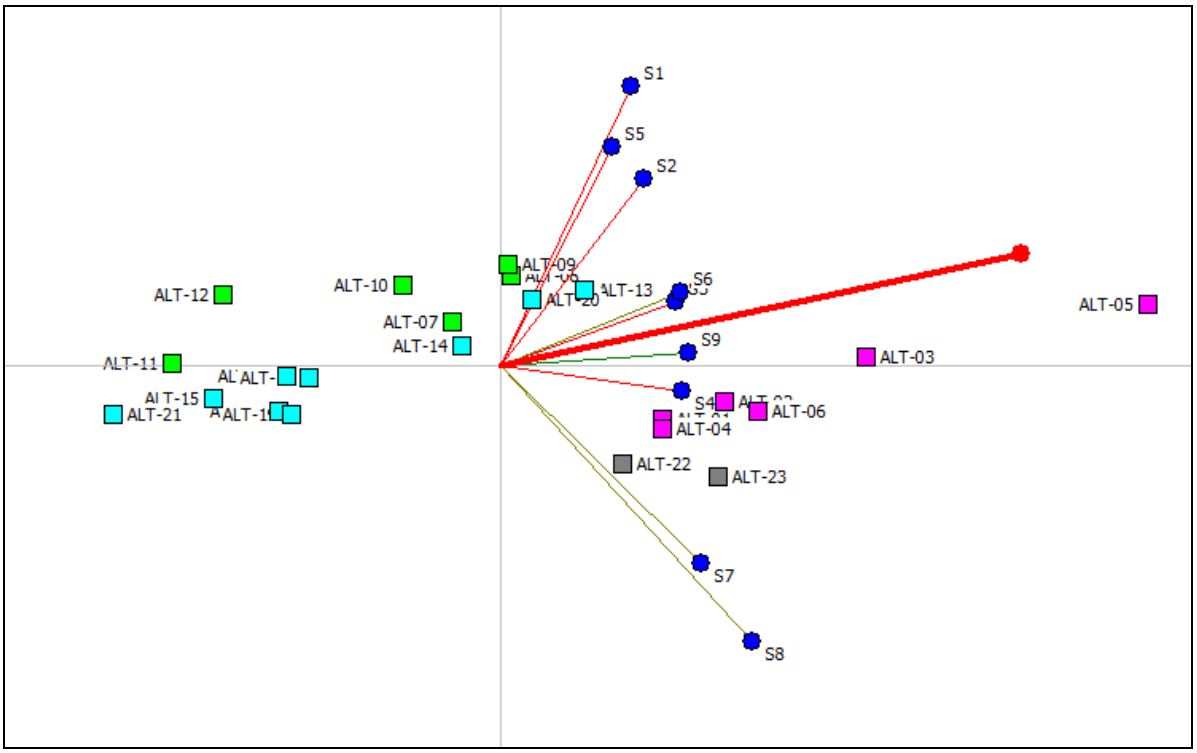


Figure 7: GAIA stakeholder map for all actions weighted for low transmission scenario

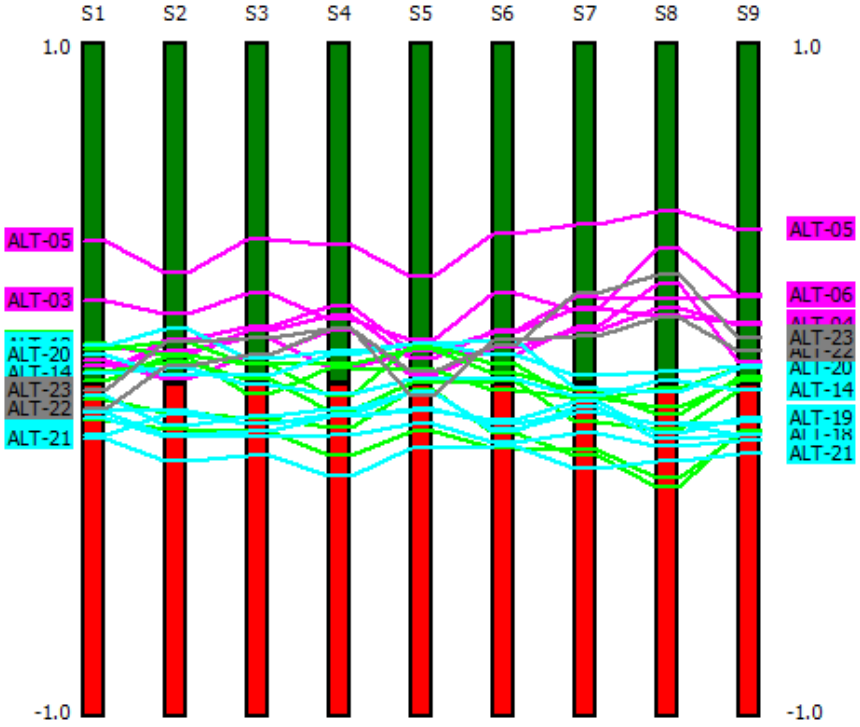


Figure 8: Individual Stakeholder rankings for low transmission scenario

In the high incidence scenario, the group ranking (Table 24) showed the 5 most interesting actions for the group of stakeholders to be ALT 5 (Large scale Lyme disease communication campaign), ALT-03 (Human vaccination), ALT-01(Excluding people from high risk areas), ALT-23(MB status quo) and ALT-02 (Discourage access to high-risk public areas). The 5 least interesting actions for the group of stakeholders are: ALT-12 (Controlled fires), ALT-18 (Rodent vaccination), ALT-15 (use of 'Damminix' devices), ALT-11 (Application of desiccants and insecticidal soap), and ALT-21 (Deer culling).

A graphical analysis of stakeholder positions relative to the group decision and evaluations of all actions shows that all stakeholders are generally in agreement with this final ordered ranking with no stakeholder in direct opposition to the final decision. Figure 9 shows a map of stakeholder positions relative to all actions with the decision axis and shows that all stakeholders are generally in agreement with the group ranking since all stakeholders are positioned in the same direction as the final decision axis. Individual stakeholder analysis as shown in figure 10 further reveals that action ALT-5 (Large scale Lyme disease communication campaign) is generally the top preferred action for all stakeholders; however, in contrast to scenario 1, this action is not a dominant action for all stakeholders.

Table 22. Rank and score of all potential actions according to all stakeholders for the high incidence transmission scenario

Rank	action	Phi	Phi+	Phi-
1	ALT-05	0,3895	0,5282	0,1386
2	ALT-03	0,2717	0,4298	0,1581
3	ALT-01	0,1441	0,3929	0,2488
4	ALT-23	0,1325	0,4040	0,2715
5	ALT-02	0,1255	0,3470	0,2216
6	ALT-06	0,1203	0,4600	0,3397
7	ALT-04	0,0761	0,4215	0,3454
8	ALT-13	0,0662	0,2972	0,2311
9	ALT-22	0,0494	0,3664	0,3170
10	ALT-08	0,0317	0,2964	0,2646
11	ALT-09	0,0282	0,2931	0,2649
12	ALT-14	0,0164	0,2759	0,2595
13	ALT-20	0,0071	0,2801	0,2730
14	ALT-07	-0,0112	0,2801	0,2914
15	ALT-10	-0,0219	0,2734	0,2953
16	ALT-17	-0,1275	0,1810	0,3085
17	ALT-16	-0,1491	0,1724	0,3215
18	ALT-19	-0,1613	0,2088	0,3701
19	ALT-12	-0,1652	0,1756	0,3408
20	ALT-18	-0,1667	0,1584	0,3251
21	ALT-15	-0,1769	0,1592	0,3360
22	ALT-11	-0,2215	0,1506	0,3720
23	ALT-21	-0,2575	0,1352	0,3926

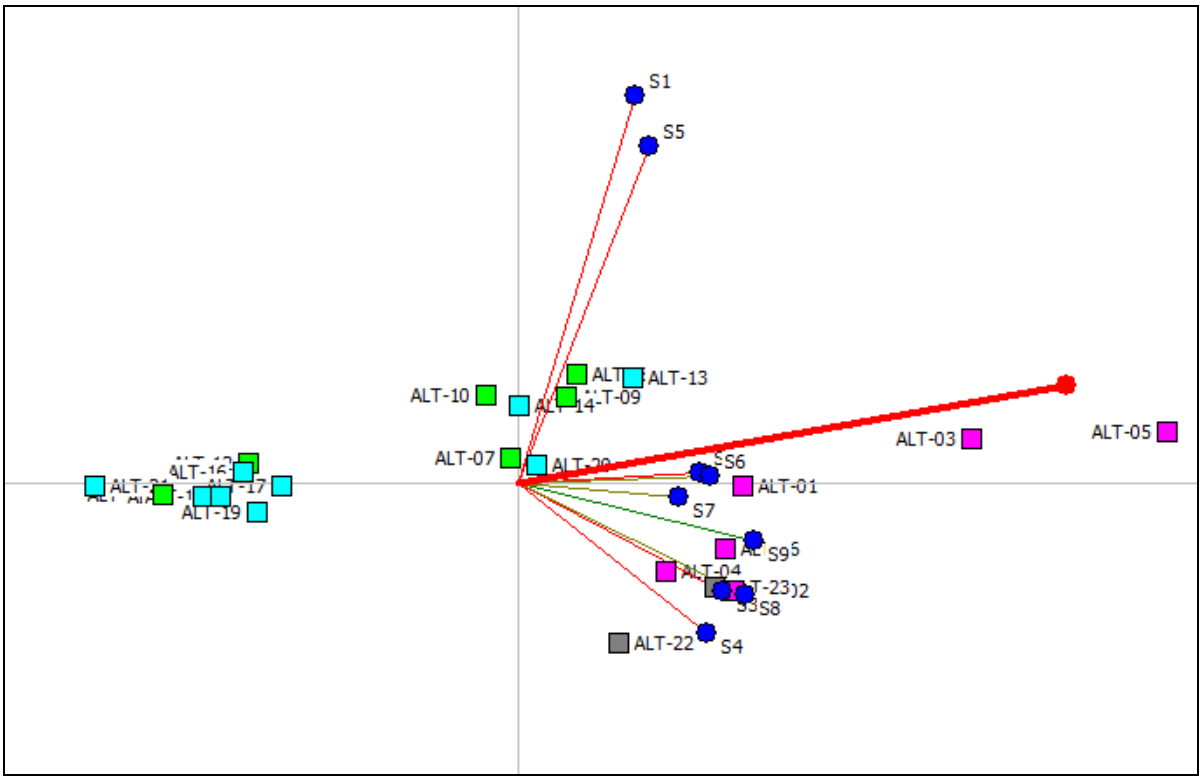


Figure 9: GAIA stakeholder map for all actions weighted for high transmission scenario

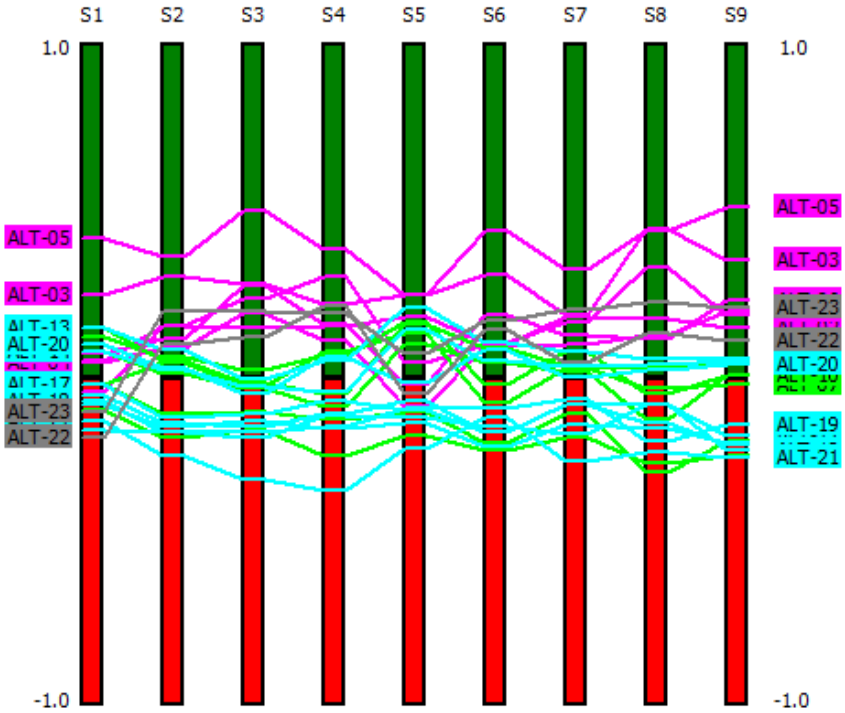


Figure 10. Individual Stakeholder rankings for high transmission scenario

Lyme model Limitations

Due to the validation nature of the Lyme component of the project, a fully iterative MCDA process was not carried out. Instead, elements from the original Quebec model were used and adapted to fit the Manitoba context following discussions with a small group of available stakeholders involved or interested in Lyme disease management. As a result, the final list of included actions and criteria were most probably influenced by and sensitive to the original Quebec parameters. A number of additional stakeholders with interests in Lyme disease management were unable to attend. Had a fully iterative process been carried out without reference to the original Quebec model, and with all potentially interested stakeholders, it is possible that important variations would have been obtained in the list of final actions and criteria retained for inclusion in the model. Furthermore, the evaluations of the actions over all criteria were contextualized for the Manitoba context based on consultation with only a small group of stakeholders. A fully iterative process and consultation with additional stakeholders and experts may have resulted in different evaluations of these parameters.

7. Conclusion and recommendations

The main objectives of this project were to examine and assemble elements important for climate sensitive disease and intervention prioritization in two contrasting study regions. These objectives were successfully achieved by means of multi-criteria decision aid processes carried out in two main contexts: a low income context and a high income context (Burkina Faso and Quebec). Preparation for the MCDA processes necessitated an extensive review of the literature contextualized for each region, as well as identification of relevant stakeholders, discussions with experts, questionnaires, statistical models, identification of relevant alternatives and criteria, the assessment of the alternatives contextualized for each region and weighting of criteria by local stakeholders. This enabled the creation of context specific matrices and context specific models analysed for both disease and intervention prioritization exercises within each region. As mentioned previously, the GIS database phase of this project was abandoned (mentioned in the first progress report sent in February 2014) rendering the integration of a GIS database into the SUPREME system no longer relevant given this adjustment. Nevertheless, the MCDA tools assessed and resulting approach for disease and intervention prioritization in a context of climate change produced as a result of this project represent an assessment of an adaptation climate change adaptation approach that is transferable and reusable by the climate change adaptation community in other health and regional contexts. The generalizable elements of the models represent solid starting models for assessment in other health contexts. These results have been made publicly available in a published scientific article (62) and presentations in scientific conferences. Two other articles are currently under review with additional articles in preparation that will further present methodological tools and aspects of this project. The existing scientific article (62), which is freely available online (open-access), serves as a guide on to how to carry out a disease prioritization process using a multicriteria decision aid approach. The intervention prioritization articles are currently under review. Furthermore, additional guidance on the construction of MCDA matrices and their application within an MCDA process are forthcoming and will be published online.

The general structure of both the disease prioritization and mosquito-borne disease intervention models were adapted separately for each context. Criteria and categories were generally similar across settings while weights varied subtly to reflect local priorities. The participation of local stakeholders allowed the addition of decision criteria of interest for the respective regions and demonstrated the added value of using a participatory approach to develop contextualized decision-aid tools. Moreover, in the intervention models, local stakeholder participation revealed a much richer range of

considerations than what is generally referenced in the malaria control literature. Given the contextual differences between the two main study regions in terms of current levels of disease transmission, general level of public and health professional awareness, management effort, and as a result, evaluation parameters for the models, differences were anticipated and found with regards to the global ranking of recommended diseases as well as intervention prioritization results.

Additionally, with regards to the fall back component added consisting of the validation of a Lyme disease model in a new context, the general structure of the original model for prevention and control interventions for Lyme disease management developed in Quebec was found to be applicable to the Manitoba context. Criteria and general interventions categories were the same and most individual criteria and interventions were kept unchanged. The participation of local stakeholders allowed the addition of decision criteria and potential interventions of interest for this province and this observation showed the added value of using a participatory approach to develop well adapted decision-aid tools. Given the contextual differences between the two provinces (Quebec and Manitoba) in terms of current levels of Lyme disease transmission, general level of public and health professional awareness, management effort, and as a result, evaluation parameters for the models, differences were anticipated and found with regards to the global ranking of recommended prevention and control actions between the two provinces. Lyme disease is currently present in Manitoba. Current annual cases of Lyme disease in Manitoba are more numerous than in Quebec at the time when the original model was first created. Different levels of public awareness and concern probably exist in Manitoba than in Quebec and similarly, different levels of public health agent risk perceptions for the disease exist. A very vocal advocacy group has put significant pressure on public health in the province to address the issue of Lyme disease in Manitoba. As a result of all of the above, the baseline level of public health effort toward Lyme disease prevention and control is already different in Manitoba than it was in Quebec at the time of the original model creation.

The MCDA approach is based on a socio-constructivist paradigm and the validity of results are not based on strict reproducibility of results, but rather representativeness of society or relevant group of experts. The validity is also intimately tied to the coherence and transparency of results that are modeling a complex system. There are limits inherent in the choice of stakeholders, but the stakeholders chosen in our studies were meant to be relevant to the dimensions at stake within the decision problem. Additional iterations with a wider set of stakeholders should be performed to assess the stability and potential diversity of modeled components in the future. MCDA can integrate multiples types of data and allows the tracking of multiple dimensions of concern often overlooked in traditional cost-benefit analysis. Additionally, the use of scenarios can enable the examination of tradeoffs between performance and acceptability under different conditions.

The evaluation of both diseases and interventions are constrained by the quality and availability of data. Where insufficient data was found, diseases or interventions were generally omitted. If local expert knowledge was available to satisfy the data needs, expert assessment was used. Otherwise, the gap in the literature was documented as a finding and informative to the process nevertheless. Additional iterations of the process can and should be performed as new data becomes available in the future.

The PROMETHEE algorithm used in the ranking processes provides a relative position for ordered items; therefore while general observations can be taken away from these analyses, such as potential disease priorities for one region over another or intervention priorities in one region or another, the actual ranking results are valid only for the current models. In other words, care should be taken in

extrapolating results from these models or interpreting the results beyond the context in which they were performed. Furthermore, middle or bottom ranked items in any of the model should not necessarily be dismissed as being “poor”, rather they are less favoured over the top ranked items in the specific model but still remain viable options to explore in future models or analyses as new options and information become available.

Disease prioritization and management of vector-borne zoonotic diseases are complex problems. Participatory decision aid approaches such as multicriteria decision analysis (MCDA) can be used to construct a rich portrait of the decision problem by structuring important elements necessary for informed decision making in a transparent fashion and aiding common shared understanding of the important decisional dimensions that need to be taken into account.

This project showed how disease prioritization as well as vector-borne and zoonotic diseases (VBZD) management models can be created and adapted to assess priorities under different contexts. Given the depth of both the model building exercises and broad similarities across regions and context in approaching public health related decisions, MCDA models are useful as a base starting point for the analysis of complex decision problems, be they decision prioritization or intervention prioritization. Further work is warranted to better understand and clarify decision making mechanisms and determinants leading to effective public health decision making under a variety of contexts.

8. References

1. Intergovernmental Panel on Climate Change (IPCC). Climate Change 2007: Synthesis Report. Cambridge University Press; 2007.
2. Iglesias A, Garrote L, Flores F, Moneo M. Challenges to manage the risk of water scarcity and climate change in the Mediterranean. Water Resour Manag. 2007;21:775–88.
3. Belanger D, Berry P, Bouchet V, Charron D, Clarke K-L, Doyon B, et al. Human Health in a Changing Climate: A Canadian Assessment of Vulnerabilities and Adaptive Capacity. Ottawa: Publications Health Canada Edited by Jacinthe Séguin; 2008 p. 494.
4. Gubler DJ. The global threat of emergent/reemergent vector-borne diseases. In: Lemon SM, Sparling PF, Hamburg MA, Relman DA, Choffnes ER, Mack A, editors. Vector-Borne Diseases: Understanding the Environmental, Human Health, and Ecological Connections, Workshop Summary (Forum on Microbial Threats). Washington, D. C.: The National Academies Press; 2008. p. 43–64.
5. Jones KE, Patel NG, Levy MA, Storeygard A, Balk D, Gittleman JL, et al. Global trends in emerging infectious diseases. Nature. 2008;451:990–3.
6. Rose JB, Huq A, Lipp EK. Health, climate and infectiouse diseases: a global perspective. Tucson, Arizona: Academy of Microbiology; 2001.
7. Linthicum KJ, Anyamba A, Britch SC, Chretien J-P, Erickson RL, Small J, et al. A Rift Valley fever risk surveillance system for Africa using remotely sensed data: potential for use on other continents. Vet Ital. 2007;43(3):663–74.
8. Auld H, MacIver D, Klaassen J. Heavy rainfall and waterborne disease outbreaks: The Walkerton example. J Toxicol Environ Health A. 2004 Oct 1;67(20–22):1879–87.
9. Haines A, Kovats RS, Campbell-Lendrum D, Corvalan C. Climate change and human health: Impacts, vulnerability and public health. Public Health. 2006;120(7):585–96.
10. Kouyaté B, Sie A, Yé M, De Allegri M, Müller O. The Great Failure of Malaria Control in Africa: A District Perspective from Burkina Faso. PLoS Med. 2007;4(6):e127.
11. (PHAC) PHAC. West Nile virus [Internet]. 2008 [cited 2008 Jun 1]. Available from: http://www.phac-aspc.gc.ca/wn-no/hist-eng.php
12. Fleury M, Charron D, Holt J, Allen O, Maarouf A. A time series analysis of the relationship of ambient temperature and common bacterial enteric infections in two Canadian provinces. Int J Biometeorol. 2006;50(6):385–91.
13. Shaman J, Day JF, Stieglitz M. Drought-Induced Amplification of Saint Louis encephalitis virus, Florida. Emerg Infect Dis. 2002;8(6):575.
14. Gagnon A, Smoyer-Tomic K, Bush A. The El Niño Southern Oscillation and malaria epidemics in South America. Int J Biometeorol. 2002 May 1;46(2):81–9.
15. Hongoh V, Berrang-Ford L, Ogden NH, Lindsay R, Scott ME, Artsob H. A review of environmental determinants and risk factors for avian-associated mosquito arboviruses in Canada. Biodiversity. 2009;10(2&3):83–91.
16. Hrudey SE, Payment P, Huck PM, Gillham RW, Hrudey EJ. A fatal waterborne disease epidemic in Walkerton, Ontario: comparison with other waterborne outbreaks in the developed world. Water Sci Technol. 2003;47(3):7–14.
17. Febriani Y, Levallois P, Gingras S, Gosselin P, Majowicz S, Fleury M. The association between farming activities, precipitation, and the risk of acute gastrointestinal illness in rural municipalities of Quebec, Canada: a cross-sectional study. BMC Public Health. 2010;10(1):48.
18. Charron DF, Thomas MK, Waltner-Toews D, Aramini JJ, Edge T, Kent RA, et al. Vulnerability of waterborne diseases to climate change in Canada: a review. J Toxicol Environ Health A. 2004 Oct 1;67(20–22):1667–77.
19. Reisen WK, Carroll BD, Takahashi R, Fang Y, Garcia S, Martinez VM, et al. Repeated West Nile virus epidemic transmission in Kern County, California, 2004-2007. J Med Entomol. 2009;46(1):139–57.
20. Diffey B. Climate change, ozone depletion and the impact on ultraviolet exposure of human skin. Phys Med Biol. 2004;49(1):R1.
21. WHO. Atlas of health and climate. Geneva, Switzerland; 2012.

22. de Bruin K, Dellink R, Ruijs A, Bolwidt L, van Buuren A, Graveland J, et al. Adapting to climate change in The Netherlands: an inventory of climate adaptation options and ranking of alternatives. Clim Change. 2009;95(1):23–45.
23. Costello A, Abbas M, Allen A, Ball S, Bell S, Bellamy R, et al. Managing the health effects of climate change: Lancet and University College London Institute for Global Health Commission. The Lancet. 2009;373(9676):1693–733.
24. Lesnikowski AC, Ford JD, Berrang-Ford L, Paterson JA, Barrera M, Heymann SJ. Adapting to health impacts of climate change: a study of UNFCCC Annex I parties. Environ Res Lett. 2011;6(4).
25. Contribution of working group III to the fourth Assessment report of the intergovernmental panel on climate change, 2007. Cambridge, United Kingdom and New York, NY, USA; 2007.
26. Füssel H-M, Klein R. Climate Change Vulnerability Assessments: An Evolution of Conceptual Thinking. Clim Change. 2006;75(3):301–29.
27. Klein RT, Nicholls R, Mimura N. Coastal Adaptation to Climate Change: Can the IPCC Technical Guidelines be applied? Mitig Adapt Strateg Glob Change. 1999 Sep 1;4(3–4):239–52.
28. Grothmann T, Patt A. Adaptive capacity and human cognition: The process of individual adaptation to climate change. Glob Environ Change. 2005;15(3):199–213.
29. Porta M, editor. A dictionary of epidemiology. 5th ed. New York: Oxford University Press; 2008.
30. Kiker GA, Bridges TS, Varghese A, Seager TP, Linkov I. Application of multicriteria decision analysis in environmental decision making. Integr Environ Assess Manag. 2005;1(2):95–108.
31. Gilliams S, Raymaekers D, Muys B, Orshoven JV. Comparing multiple criteria decision methods to extend a geographical information system on afforestation. Comput Electron Agric. 2005;49(1):142–58.
32. Fealy RM, Buckley C, Mechan S, Melland A, Mellander PE, Shortle G, et al. The Irish agricultural catchments programme: Catchment selection using spatial multi-criteria decision analysis. Soil Use Manag. 2010;26(3):225–36.
33. Ellis JB, Deutsch JC, Mouchel JM, Scholes L, Revitt MD. Multicriteria decision approaches to support sustainable drainage options for the treatment of highway and urban runoff. Sci Total Environ. 2004;334–335:251–60.
34. Papazoglou IA. Risk informed decision making in land use planning. 2000;
35. Baltussen R, Niessen L. Priority setting of health interventions: the need for multi-criteria decision analysis. Cost Eff Resour Alloc. 2006;4(1):14.
36. Baltussen R, Youngkong S, Paolucci F, Niessen L. Multi-criteria decision analysis to prioritize health interventions: Capitalizing on first experiences. Health Policy [Internet]. 2010; Available from: http://www.scopus.com/inward/record.url?eid=2-s2.0-77449140038&partnerID=40&md5=1fa17989e85543760035824eb2fb60d8
37. Macharis C, Mareschal B, Waaub J-P, Milan L. PROMETHEE-GDSS revisited: applications so far and new developments. Int J Multicriteria Decis Mak.
38. Bots PWG, Hulshof JAM. Designing multi-criteria decision analysis processes for priority setting in health policy. J Multi-Criteria Decis Anal. 2000;9(1–3):56–75.
39. Vahidnia MH, Alesheikh AA, Alimohammadi A. Hospital site selection using fuzzy AHP and its derivatives. J Environ Manage. 2009;90(10):3048–56.
40. Higgs G. Integrating multi-criteria techniques with geographical information systems in waste facility location to enhance public participation. Waste Manag Res. 2006;24:105–17.
41. Seager TP, Lambert JH, Gardner KH. Fostering Innovation in Contaminated Sediments Management Through Multicriteria Technology Assessment and Public Participation. Risk Anal. 2007;27(4):1043–52.
42. Bellehumeur C, Vasseur L, Ansseau C, Marcos B. Implementation of a multicriteria sewage sludge management model in the southern Quebec municipality of Lac-Megantic, Canada. J Environ Manage. 1997;50(1):51–66.
43. Khadam IM, Kaluarachchi JJ. Multi-criteria decision analysis with probabilistic risk assessment for the management of contaminated ground water. Environ Impact Assess Rev. 2003;23(6):683–721.
44. Brent AC, Rogers DEC, Ramabitsa-Siimane TSM, Rohwer MB. Application of the analytical hierarchy process to establish health care waste management systems that minimise infection risks in developing countries. Eur J Oper Res. 2007;181(1):403–24.

45. Pruyt E, Wijnmalen D. National Risk Assessment in The Netherlands - A Multiple Criteria Decision Making for Sustainable Energy and Transportation Systems. In: Ehrgott M, Naujoks B, Stewart TJ, Wallenius J, editors. Springer Berlin Heidelberg; 2010. p. 133–43. (Lecture Notes in Economics and Mathematical Systems; vol. 634). Available from: http://dx.doi.org/10.1007/978-3-642-04045-0_11
46. Levy JK. Multiple criteria decision making and decision support systems for flood risk management. Stoch Environ Res Risk Assess. 2005;19(6):438–47.
47. Bana e Costa CA, Antão da Silva P, Nunes Correia F. Multicriteria Evaluation of Flood Control Measures: The Case of Ribeira do Livramento. Water Resour Manag. 2004;18(3):263–83.
48. Mt-Isa S, Tzoulaki I, Callréus T, Micaleff A, Ashby D. Weighing benefit–risk of medicines: concepts and approaches. Drug Discov Today Technol. 2011;8(1):e29–35.
49. Peacock S, Mitton C, Bate A, McCoy B, Donaldson C. Overcoming barriers to priority setting using interdisciplinary methods. Health Policy. 2009;92(2–3):124–32.
50. Ruzante JM, Davidson VJ, Caswell J, Fazil A, Cranfield JAL, Henson SJ, et al. A multifactorial risk prioritization framework for foodborne pathogens. Risk Anal. 2010;30(5):724–42.
51. Husereau D, Boucher M, Noorani H. Priority setting for health technology assessment at CADTH. Int J Technol Assess Health Care. 2010;26(3):341–7.
52. Tony M, Wagner M, Khoury H, Rindress D, Papastavros T, Oh P, et al. Bridging health technology assessment (HTA) with multicriteria decision analyses (MCDA): field testing of the EVIDEM framework for coverage decisions by a public payer in Canada. BMC Health Serv Res. 2011;11(1):329.
53. Nutt DJ, King LA, Phillips LD. Drug harms in the UK: a multicriteria decision analysis. The Lancet. 2010;376(9752):1558–65.
54. Wenstøp F, Magnus P. Value focused rationality in AIDS policy. Health Policy. 2001;57(1):57–72.
55. Baltussen R, ten Asbroek AHA, Koolman X, Shrestha N, Bhattarai P, Niessen LW. Priority setting using multiple criteria: should a lung health programme be implemented in Nepal? Health Policy Plan. 2007 May 1;22(3):178–85.
56. Youngkong. Multi-criteria decision analysis for setting priorities on HIV/AIDS interventions in Thailand. Health Res Policy Syst. 2012;10(6).
57. Youngkong S, Baltussen R, Tantivess S, Koolman X, Teerawattananon Y. Criteria for priority setting of HIV/AIDS interventions in Thailand: a discrete choice experiment. BMC Health Serv Res. 2010;10(1):197.
58. Defechereux T. Health care priority setting in Norway a multicriteria decision analysis. 2012;
59. Jehu-Appiah C, Baltussen R, Acquah C, Aikins M, Amah d'Almeida S, Bosu WK, et al. Balancing equity and efficiency in health priorities in Ghana: the use of multicriteria Decision Analysis. Value Health. 2008;11(7):1081–7.
60. Pinheiro PR, Castro A, Pinheiro M. A Multicriteria Model Applied in the Diagnosis of Alzheimer's Disease: A Bayesian Network. In 2008. p. 15–22.
61. Wilson E, Rees J, Fordham R. Developing a prioritisation framework in an English Primary Trust. Cost Eff Resour Alloc. 2006;4(3).
62. Hongoh V, Michel P, Gosselin P, Samoura K, Ravel A, Campagna C, et al. Multi-Stakeholder Decision Aid for Improved Prioritization of the Public Health Impact of Climate Sensitive Infectious Diseases. Int J Environ Res Public Health. 2016;13(4):419.
63. Morgan DL. Focus groups as qualitative research. Second Edition. Thousand Oaks, California: Sage Publications, Inc; 1997. (Qualitative research methods; vol. 16).
64. Petersen LR, Brault AC, Nasci RS. West nile virus: Review of the literature. JAMA-J Am Med Assoc. 2013 Jul 17;310(3):308–15.
65. Reisen W, Brault AC. West Nile virus in North America: perspectives on epidemiology and intervention. Pest Manag Sci. 2007 Jul;63(7):641–6.
66. Nasci RS, Fischer M, Lindsey NP, Lanciotti RS, Savage HM, Komar N, et al. West Nile virus in the United States: guidelines for surveillance, prevention and control. Centers for Disease Control and Prevention; 2013.
67. Labbé Y, Aubé-Maurice B, Vézina A, Boisvert J, Gingras D. Revue des mesures de prévention et de protection contre le virus du Nil occidental. Institut national de santé publique du Québec; 2006 p. 173. (Étude d'impact stratégique du Plan d'intervention gouvernemental de protection de la santé publique contre le virus du Nil occidental).

68. Tran A, Sudre B, Paz S, Rossi M, Desbrosse A, Chevalier V, et al. Environmental predictors of West Nile fever risk in Europe. Int J Health Geogr. 2014;13(26).
69. Paz S, Semenza JC. Environmental Drivers of West Nile Fever Epidemiology in Europe and Western Asia—A Review. Int J Environ Res Public Health. 2013;10(8):3543.
70. Sawford K, Dhand N, Toribio J-A, Taylor M. The use of a modified Delphi approach to engage stakeholders in zoonotic disease research priority setting. BMC Public Health. 2014;14(1):182.
71. Aenishaenslin C, Hongoh V, Cisse H, Hoen A, Samoura K, Michel P, et al. Multi-criteria decision analysis as an innovative approach to managing zoonoses: results from a study on Lyme disease in Canada. BMC Public Health. 2013;13(1):897.
72. Jones J, Hunter D. Consensus methods for medical and health services research. BMJ. 1995;311:376–80.
73. Morestin F, Gauvin F, Hogue M, Benoit F. Method for synthesizing knowledge about public policies [Internet]. National Collaborating Centre for Healthy Public Policy; 2011. Available from: http://www.ncchpp.ca/docs/methodPP_EN.pdf
74. Brans JP, Vincke P. A Preference Ranking Organisation Method: (The PROMETHEE Method for Multiple Criteria Decision-Making). Manag Sci. 1985;31(6):647–56.
75. Gubler DJ, Reiter P, Ebi KL, Yap W, Nasci R, Patz JA. Climate variability and change in the United States: potential impacts on vector - and rodent-borne diseases. Environ Health Perspect. 2001;109(Supplement 2).
76. McGregor S, Henderson KJ, Kaldor JM. How Are Health Research Priorities Set in Low and Middle Income Countries? A Systematic Review of Published Reports. PLoS ONE [Internet]. 2014;9(10). Available from: http://dx.doi.org/10.1371%2Fjournal.pone.0108787
77. Burton I, Huq S, Lim B, Pilifosova O, Schipper EL. From impacts assessment to adaptation priorities: the shaping of adaptation policy. Clim Policy. 2002;2(2–3):145–59.
78. Moore CG, Mitchel CJ. Aedes albopictus in the United States: ten-year presence and public health implications. Emerg Infect Dis. 1997;3(3):329–34.
79. Ogden N, Milka R, Caminade C, Gachon P. Recent and projected future climatic suitability of North America for the Asian tiger mosquito Aedes albopictus. Parasit Vectors. 2014;7(1):532.
80. Berrang-Ford L, McLean JD, Gyorkos TW, Ford JD, Ogden NH. Climate change and Malaria in Canada: a systems approach. Interdiscip Perspect Infect Dis. 2009;2009:13.
81. Patz JA, Githeko AK, McCarty JP, Hussein S, Confalonieri U, de Wet N. Climate change and infectious diseases. In: McMichael AJ, Campbell-Lendrum DH, Corvalan CF, Ebi KL, Githeko AK, Scheraga JD, et al., editors. Climate change and human health: risks and responses. Geneva, Switzerland: World Health Organization; 2003. p. 322.
82. Medlock JM, Leach SA. Effect of climate change on vector-borne disease risk in the UK. Lancet Infect Dis. 2015;15(6):721–30.
83. McArthur MA, Edelman R. A Promising, Single-Dose, Live Attenuated Tetravalent Dengue Vaccine Candidate. J Infect Dis [Internet]. 2015 Mar 22; Available from: http://jid.oxfordjournals.org/content/early/2015/03/22/infdis.jiv086.short
84. Ridde V, Carabali M, Ly A, Druetz T, Kouanda S, Bonnet E, et al. The Need for More Research and Public Health Interventions on Dengue Fever in Burkina Faso. PLoS Negl Trop Dis [Internet]. 2014;8(6). Available from: http://dx.doi.org/10.1371%2Fjournal.pntd.0002859
85. Ng V, Sargeant JM. A stakeholder-informed approach to the identification of criteria for the prioritization of zoonoses in Canada. PLoS ONE. 2012;7(1):e29752.
86. Bolduc D, Ricard S, Québec I national de santé publique du. Cadre de référence en gestion des risques pour la santé dans le réseau québécois de la santé publique. [Montréal]: Institut national de santé publique du Québec; 2003.
87. Ross W, Birkwood P, Henter T, Krewski D, Muise AM, Nahas A. Health Canada Decision-Making Framework for Identifying, Assessing, and Managing Health Risks - August 1, 2000 [Internet]. Health Canada; 2000 [cited 2015 Sep 25]. Available from: http://www.hc-sc.gc.ca/ahc-asc/pubs/hpfb-dgpsa/risk-risques_tc-tm-eng.php
88. Gouvernement du Québec. Portail santé mieux-être [Internet]. Se protéger des piqûres de moustiques et de tiques. 2015 [cited 2015 Jul 27]. Available from: http://www.xn--sant-epa.gouv.qc.ca/conseils-et-prevention/se-proteger-des-piqures-de-moustiques/

89. Government of Canada. Healthy Canadians [Internet]. Prevention of West Nile virus. 2015 [cited 2015 Jul 27]. Available from: http://healthycanadians.gc.ca/diseases-conditions-maladies-affections/disease-maladie/west-nile-nil-occidental/prevention-eng.php
90. CDC. West Nile virus [Internet]. Centers for Disease Control and Prevention. 2015 [cited 2015 Jul 27]. Available from: http://www.cdc.gov/westnile/prevention/index.html
91. Bellini R, Zeller H, Bortel WV. A review of the vector management methods to prevent and control outbreaks of West Nile infection and the challenge for Europe. Parasit Vectors. 2014;7(323).
92. Grondin J, Corriveau R, Bolduc D, Brunel M. Virus du nil occidental : Évaluation des attitudes, Des comportements et des Connaissances populaires. Institut national de santé publique; 2003.
93. Stockwell PJ, Wessell N, Reed DR, Kronenwetter-Koepel TA, Reed KD, Turchi TR, et al. A field evaluation of four larval mosquito control methods in urban catch basins. J Am Mosq Control Assoc. 2006 Dec 1;22(4):666–71.
94. Hribar LJ, Fussell EM, Leal AL. Larviciding Offshore Islands Reduces Adulticidal Treatment of Populated Areas Adjacent To National Wildlife Refuges. J Am Mosq Control Assoc. 2011 Dec 1;27(4):408–13.
95. Townson H, Nathan M, Zaim M, Guillet P, Manga L, Bos R, et al. Exploiting the potential of vector control for disease prevention. Bull World Health Organ. 2005;83:942–7.
96. Bunning ML, Fox PE, Bowen RA, Komar N, Chang G-JJ, Speaker TJ, et al. DNA Vaccination of the American Crow (Corvus brachyrhynchos) Provides Partial Protection Against Lethal Challenge with West Nile Virus. Avian Dis. 2007;51(2):573–7.
97. Kilpatrick AM, Dupuis AP, Chang G-JJ, Kramer LD. DNA Vaccination of American Robins (Turdus migratorius) Against West Nile Virus. Vector-Borne Zoonotic Dis. 2010;10(4):377–80.
98. Young JA, Jefferies W. Towards the Conservation of Endangered Avian Species: A Recombinant West Nile Virus Vaccine Results in Increased Humoral and Cellular Immune Responses in Japanese Quail (Coturnix japonica). PLoS ONE. 2013;8(6):e67137.
99. Harbison JE, Metzger ME, Hu R. Association Between Culex quinquefasciatus (Diptera: Culicidae) Oviposition and Structural Features of Belowground Stormwater Treatment Devices. J Med Entomol. 2010;47(1):67–73.
100. Vazquez-Prokopec G, Vanden Eng JL, Kelly R, Mead DG, Kolhe P, Howgate J, et al. The risk of West Nile virus infection is associated with combined sewer overflow streams in Urban Atlanta, Georgia, USA. Environ Health Perspect. 2010;118(19):1382–8.
101. Lund A, McMillan J, Kelly R, Jabbarzadeh S, Mead DG, Burkot TR, et al. Long term impacts of combined sewer overflow remediation on water quality and population dynamics of Culex quinquefasciatus, the main urban West Nile virus vector in Atlanta, GA. Environ Res. 2014;129(0):20–6.
102. Ministère de la Santé et des Services sociaux. Plan d'intervention gouvernemental 2013-2015 pour la protection de la population contre le virus du Nil occidental Mise à jour - Saison 2014. 2014.
103. Greco S, Matarazzo B, Slowinski R. Dealing with Missing Data in Rough Set Analysis of Multi-Attribute and Multi-Criteria Decision Problems. In: Zanakis S, Doukidis G, Zopounidis C, editors. Decision Making: Recent Developments and Worldwide Applications [Internet]. Springer US; 2000. p. 295–316. (Applied Optimization; vol. 45). Available from: http://dx.doi.org/10.1007/978-1-4757-4919-9_20
104. World Health Organization. World Malaria Report 2012. Geneva, Switzerland; 2012.
105. Brieger B, Badolo O, Yansaneh A, Waxman R, Roman E. A documentation of Malaria Program implementation in Burkina Faso. Baltimore, Maryland, USA; 2013.

9. Appendices

Appendix 1 – West Nile virus risk transmission scenarios

Risk transmission scenarios assessed under the MCDA model for West Nile virus interventions in Quebec.

Scenario	Scenario description	Management context and interventions advocated for WNV season underway
1 **low-risk** - *without interventions* - « Current », end of season, low intensity – Decision for next year	At the end of September, 26 cases declared. All declared cases are symptomatic and distributed among two of the nine socio-sanitary regions of Quebec within which human transmission of WNV were previously documented. Clinical presentation of cases was consistent with literature reported symptoms. Passive surveillance of equines (MAPAQ) and of wildlife birds (CQSAS) is coherent with human surveillance data (with respect to the number and geographical distribution of cases). Entomological surveillance data suggests a high density of mosquitoes for the current season, but little WNV found in circulation at present.	Since few WNV cases declared in past two years (< 10) and few resources available to coordinate interventions at beginning of the season, primary intervention strategy for the current season has primarily consisted of providing WNV related information on the ministry website (MSSS)
2 **low-risk -** *with interventions* - « Current », end of season, low intensity - Decision for next year	At the end of September, 26 cases declared. All declared cases are symptomatic and distributed among two of the nine socio-sanitary regions of Quebec within which human transmission of WNV were previously documented. Clinical presentation of cases was consistent with literature reported symptoms. Passive surveillance of equines (MAPAQ) and of wildlife birds (CQSAS) is coherent with human surveillance data (with respect to the number and geographical distribution of cases). Entomological surveillance data suggests a high density of mosquitoes for the current season, but little WNV found in circulation at present.	Previous year, 23 cases declared. WNV a concern for Quebec population. Series of interventions carried out at beginning of transmission season. Primary interventions at provincial level: providing WNV related information on ministry website (MSSS). Application of larvicides within risk zones. Calls for vigilance to network medical practitioners. Large scale communication campaign
3 **medium-risk - *without*** interventions - « Outbreak», mid-season, high intensity – Rapid decision for current season	At end of July, 40 symptomatic cases declared to ministry. (Historically, majority of cases occur mid-Aug.-Sep.). 10 cases from regions where no human or animal cases have ever been recorded, suggesting geographical expansion of virus into new zones. Meteorological forecasts predict hot and dry summer. Passive surveillance of equines (MAPAQ) and wildlife (CQSAS) coherent with human surveillance data and suggest acute viral activity compared with data collected over past two years. Among WNV infected horses, 3 declared from regions where no human cases were previously declared and where WNV virus circulation never previously recorded. Entomological surveillance data suggest an increase in mosquito activity and circulation of virus (high density of Culex pipiens and high level of infection). Past two weeks, vector index (number of infected mosquitoes) on rise.	Since few WNV cases declared in past two years (< 10) and few resources available to coordinate interventions at beginning of the season, primary intervention strategy for the current season: providing WNV related information on the ministry website (MSSS)
4 **medium-risk -*with interventions*** - « Outbreak», mid-season,	At end of July, 40 symptomatic cases declared to ministry. (Historically, majority of cases occur mid-Aug.-Sep.). 10 cases from regions where no human or animal cases have ever been recorded, suggesting geographical expansion of virus into new zones. Meteorological forecasts predict hot and dry summer. Passive surveillance of equines (MAPAQ) and wildlife (CQSAS) coherent with human surveillance data and suggest acute	Previous year, 23 cases declared. WNV a concern for Quebec population. Series of interventions carried out at beginning of transmission season. Primary interventions at provincial level: providing WNV related

high intensity – Rapid decision for current season	viral activity compared with data collected over past two years. Among WNV infected horses, 3 declared from regions where no human cases were previously declared and where WNV virus circulation never previously recorded. Entomological surveillance data suggest an increase in mosquito activity and circulation of virus (high density of Culex pipiens and high level of infection). Past two weeks, vector index (number of infected mosquitoes) on rise.	information on ministry website (MSSS). Application of larvicides within risk zones. Calls for vigilance to network medical practitioners. Large scale communication campaign
5 **high-risk** - *without interventions* - « Epidemic», end of season, high intensity - Decision for next year	End of September, 800 symptomatic cases declared. 40 cases from regions where no animal or human cases previously recorded, suggesting a geographical expansion of the virus into new zones. Passive surveillance of equines (MAPAQ) and wildlife (CQSAS) are coherent with human surveillance data and appear to suggest acute viral activity compared with data collected over past two years. Among WNV infected horses, 12 declared from regions where no human cases were previously declared and where virus circulation never previously recorded. Moreover, 72 birds submitted to CQSAS (passive surveillance) tested positive for WNV. Entomological surveillance suggests an increase in mosquito activity and circulation of virus (high density of Culex pipiens and high level of infection). Past four weeks, vector index (number of infected mosquitoes) increasing significantly.	Since few WNV cases declared in last two years (< 10) and few resources available to coordinate interventions at beginning of the season, primary intervention strategy for the current season: providing WNV related information on the ministry website (MSSS)
6 **high-risk** - *with interventions* - « Epidemic», end of season, high intensity - Decision for next year	End of September, 800 symptomatic cases declared. 40 cases from regions where no animal or human cases previously recorded, suggesting a geographical expansion of the virus into new zones. Passive surveillance of equines (MAPAQ) and wildlife (CQSAS) are coherent with human surveillance data and appear to suggest acute viral activity compared with data collected over past two years. Among WNV infected horses, 12 declared from regions where no human cases were previously declared and where virus circulation never previously recorded. Moreover, 72 birds submitted to CQSAS (passive surveillance) tested positive for WNV. Entomological surveillance suggests an increase in mosquito activity and circulation of virus (high density of Culex pipiens and high level of infection). Past four weeks, vector index (number of infected mosquitoes) increasing significantly.	Previous year, 23 cases declared. WNV a concern for Quebec population. Series of interventions carried out at beginning of transmission season. Primary interventions at provincial level: providing WNV related information on ministry website (MSSS). Application of larvicides within risk zones. Calls for vigilance to network medical practitioners. Large scale communication campaign

Appendix 2 – Quebec stakeholder weights for scenarios

Criteria weighting by QC stakeholders for SC2

		Act 1	Act 3	Act 2	Act 4	Act 5	Act 10	Act 6	Act 7	Act 8	Act 9	Act 11
SP	SP-01	16	9	10	12	11	8.75	15	16	14	0	16.96
	SP-02	8	3	10	12	11	5	0	8	6	0	5.3
	SP-03	4	3	5	0	3	7.5	20	4	4	8	2.65
	SP-04	4	3	5	6	3	2	10	4	2	2	2.65
	SP-05	2	3	5	0	1	0.5	2.5	4	2	0	2.65
	SP-06	2	3	5	0	1	0.5	0	0	6	0	2.65
	SP-07	4	6	10	0	20	0.75	2.5	4	6	0	20.14
PC	PC-01	2	7	5	10	2.5	2	5	5	8	0	5.25
	PC-02	3	3	5	10	2.5	8	5	5	2	0	9.75
EC	EC-01	7.5	5	7.5	0	6.8	10	6.25	10	32	40	1.75
	EC-02	2.5	5	5.25	5	6.6	7.5	6.25	5	6	40	1.75
	EC-03	15	10	2.25	5	6.6	7.5	12.5	5	2	0	1.5
OP	OP-01	6	5.25	4	9	7.5	6	2.5	5	2.4	0	6.25
	OP-02	4	2.25	7	9	3.75	6	2.5	5	2.4	0	7.5
	OP-03	8	6	7	12	1.95	6	2.5	5	2	0	5
	OP-04	2	1.5	2	0	1.8	2	2.5	5	1.2	0	6.25
SAE	SAE-01	5	10	2.5	3	5	10	2.5	5	0.8	1	1.2
	SAE-02	5	15	2.5	7	5	10	2.5	5	1.2	9	0.8

Criteria weighting by QC stakeholders for SC3

		Act 1	Act 3	Act 2	Act 4	Act 5	Act 10	Act 6	Act 7	Act 8	Act 9	Act 11
SP	SP-01	16	10.5	15	12	11	5	20	18	10	0	17.5
	SP-02	8	3.5	10	6	11	3.75	0	12	12.5	0	10
	SP-03	4	3.5	5	6	3	7.5	15	4	12.5	40	2.5
	SP-04	4	3.5	5	6	3	1.25	5	2	5	10	1
	SP-05	2	3.5	5	0	1	2.5	5	2	2.5	0	1.5
	SP-06	2	3.5	0	0	1	2.5	0	0	2.5	0	2.5
	SP-07	4	7	10	0	20	2.5	0	2	5	0	15
PC	PC-01	2	7	2.5	10	2.5	12	10	7.5	8	0	2
	PC-02	3	3	2.5	10	2.5	18	15	7.5	2	0	8
EC	EC-01	7.5	2.5	5	0	3.4	12.5	20	3.5	15	10	6
	EC-02	2.5	2.5	3.5	5	3.3	7.5	0	3.5	3	10	7
	EC-03	15	5	1.5	5	3.3	5	0	3	2	0	7
OP	OP-01	6	10.5	6	9	24	1.5	10	12	6	1	10.8
	OP-02	4	4.5	10.5	9	4.5	1.25	0	10.5	3	6	1.8
	OP-03	8	12	10.5	12	0.9	1.75	0	6	6	1	2.7
	OP-04	2	3	3	0	0.6	0.5	0	1.5	0	2	2.7
SAE	SAE-01	5	6	2.5	5	2.5	6	0	2.5	2.5	6	1.5
	SAE-02	5	9	2.5	5	2.5	9	0	2.5	2.5	14	0.5

Criteria weighting by QC stakeholders for SC4

		Act 1	Act 3	Act 2	Act 4	Act 5	Act 10	Act 6	Act 7	Act 8	Act 9	Act 11
SP	SP-01	16	10.5	15	12	12	4	20	14	12.5	0	16.5
	SP-02	8	3.5	10	6	12	3	0	10	10	0	11
	SP-03	4	3.5	5	6	3	6	15	6	12.5	48	2.75
	SP-04	4	3.5	5	6	3	1	5	4	4	12	1.1
	SP-05	2	3.5	5	0	0	2	5	2	1	0	1.65
	SP-06	2	3.5	0	0	0	2	0	0	5	0	2.75
	SP-07	4	7	10	0	20	2	0	4	5	0	19.25
PC	PC-01	2	7	2.5	10	2.5	8	10	7.5	17	0	3
	PC-02	3	3	2.5	10	2.5	12	15	7.5	3	0	12
EC	EC-01	7.5	3.75	5	0	3.4	12.5	20	5.25	15	10	1.5
	EC-02	2.5	3.75	3.5	5	3.3	7.5	0	5.25	3	10	1.75
	EC-03	15	7.5	1.5	5	3.3	5	0	4.5	2	0	1.75
OP	OP-01	6	7	6	9	24	6	10	8	3.2	2.22	17.25
	OP-02	4	3	10.5	9	4.5	5	0	7	1.6	2.78	2.3
	OP-03	8	8	10.5	12	0.9	7	0	4	3.2	2.78	1.15
	OP-04	2	2	3	0	0.6	2	0	1	0	2.22	2.3
SAE	SAE-01	5	8	2.5	5	2.5	6	0	5	1	4	1.5
	SAE-02	5	12	2.5	5	2.5	9	0	5	1	6	0.5

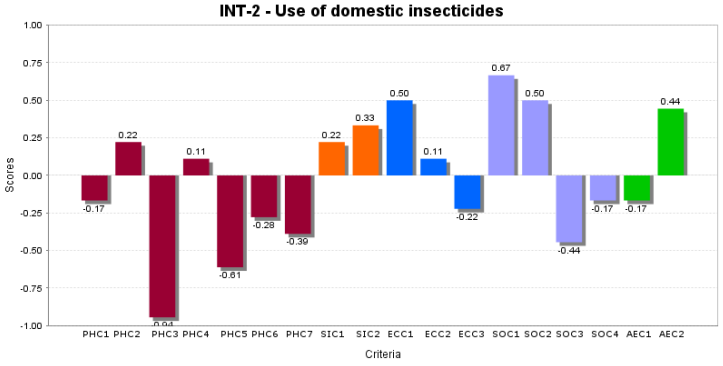
Criteria weighting by QC stakeholders for SC5

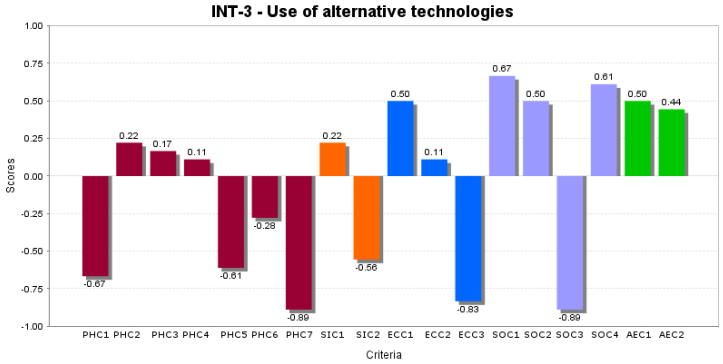
		Act 1	Act 3	Act 2	Act 4	Act 5	Act 10	Act 6	Act 7	Act 8	Act 9	Act 11
SP	SP-01	16	15	10	8	11	6	40	14	18	13	17.6
	SP-02	8	7.5	10	0	11	4.5	0	8	15	0	11
	SP-03	4	5	5	8	3	9	20	8	21	35.8	2.75
	SP-04	4	5	5	8	3	3	0	4	0	16.3	1.1
	SP-05	2	5	5	0	1	1.5	0	2	0	0	1.65
	SP-06	2	7.5	5	8	1	3	0	2	3	0	5.5
	SP-07	4	5	10	8	20	3	0	2	3	0	15.4
PC	PC-01	2	3.5	5	15	2.5	12.5	0	10	1.4	12.5	1.75
	PC-02	3	1.5	5	15	2.5	12.5	20	10	0.6	12.5	3.25
EC	EC-01	7.5	2.5	5	4	6.8	10	5	10	27	0	8
	EC-02	2.5	2.5	3.5	4	6.6	6	0	5	3	0	7
	EC-03	15	5	1.5	2	6.6	4	0	5	0	0	5
OP	OP-01	6	8.75	5	0	7.5	1.5	15	1.5	1.5	0	6
	OP-02	4	3.75	8.75	5	3.75	1.25	0	6	3.6	0	2.25
	OP-03	8	10	8.75	5	1.95	1.75	0	6	0.9	0	2.25
	OP-04	2	2.5	2.5	0	1.8	0.5	0	1.5	0	0	4.5
SAE	SAE-01	5	4	2.5	5	5	8	0	2.5	0.8	3	2.5
	SAE-02	5	6	2.5	5	5	12	0	2.5	1.2	7	2.5

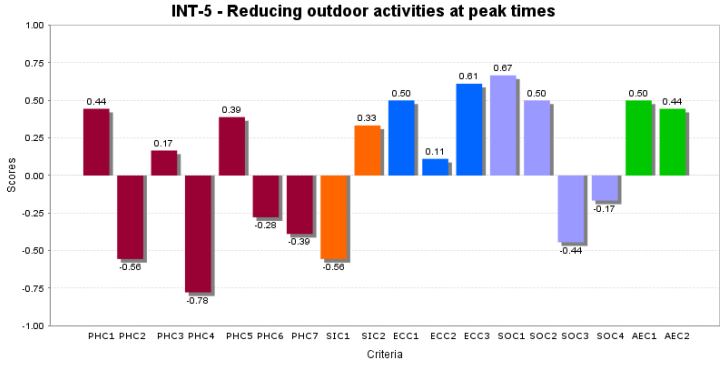
Criteria weighting by QC stakeholders for SC6

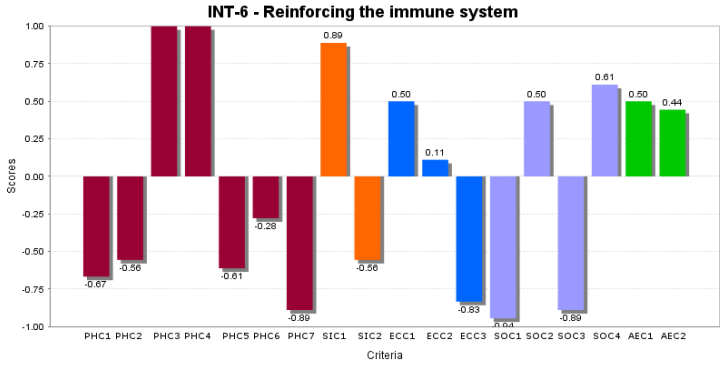
		Act 1	Act 3	Act 2	Act 4	Act 5	Act 10	Act 6	Act 7	Act 8	Act 9	Act 11
SP	SP-01	16	15	10	8	11	5	16	14	24	13	15.4
	SP-02	8	7.5	10	0	11	3.75	0	8	24	0	11
	SP-03	4	5	5	8	3	7.5	8	8	28	35.8	2.75
	SP-04	4	5	5	8	3	1.25	8	4	0	16.3	1.1
	SP-05	2	5	5	0	1	2.5	4	2	0	0	1.65
	SP-06	2	7.5	5	8	1	2.5	0	2	2.4	0	5.5
	SP-07	4	5	10	8	20	2.5	4	2	1.6	0	17.6
PC	PC-01	2	3.5	5	10	2.5	8	5	10	0.7	12.5	5.25
	PC-02	3	1.5	5	10	2.5	12	5	10	0.3	12.5	9.75
EC	EC-01	7.5	2.5	5	8	6.8	15	30	7.5	13.5	0	2
	EC-02	2.5	2.5	3.5	8	6.6	7.5	0	3.75	1.5	0	1.75
	EC-03	15	5	1.5	4	6.6	2.5	0	3.75	0	0	1.25
OP	OP-01	6	8.75	5	0	7.5	6	2.5	1.5	0.6	0	8
	OP-02	4	3.75	8.75	5	3.75	5	2.5	4.5	1.8	0	3
	OP-03	8	10	8.75	5	1.95	7	2.5	7.5	0.6	0	3
	OP-04	2	2.5	2.5	0	1.8	2	2.5	1.5	0	0	6
SAE	SAE-01	5	4	2.5	5	5	5	5	5	0.4	3	2.5
	SAE-02	5	6	2.5	5	5	5	5	5	0.6	7	2.5

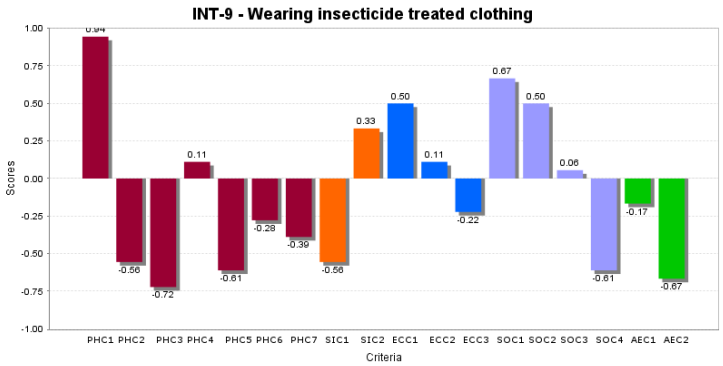
Appendix 3 – West Nile virus intervention profiles

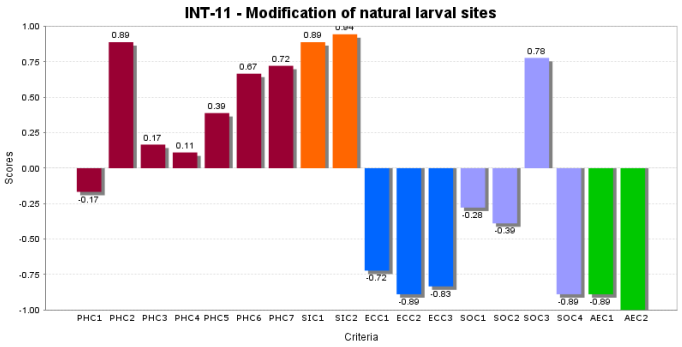


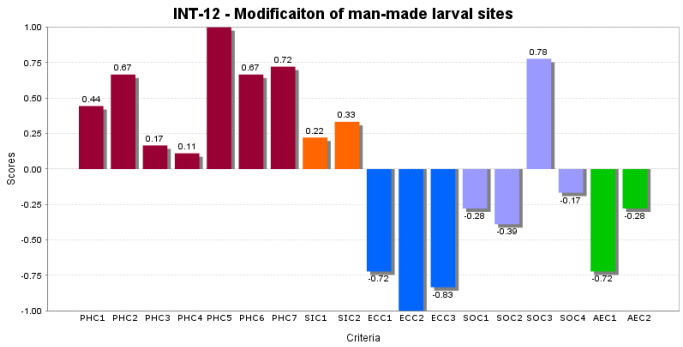


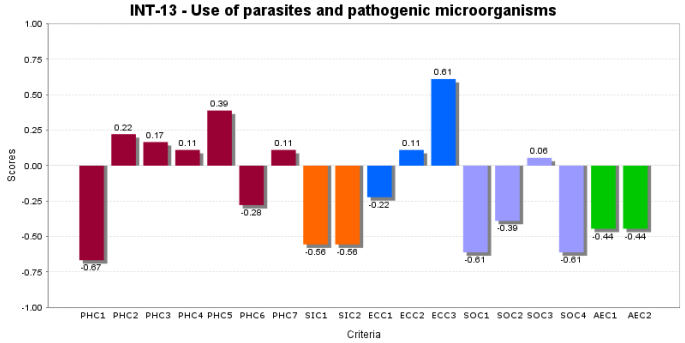


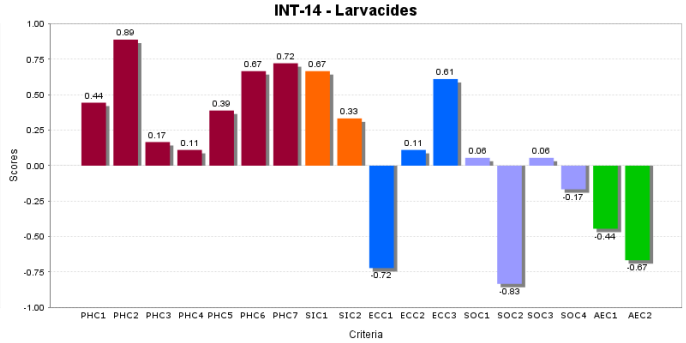


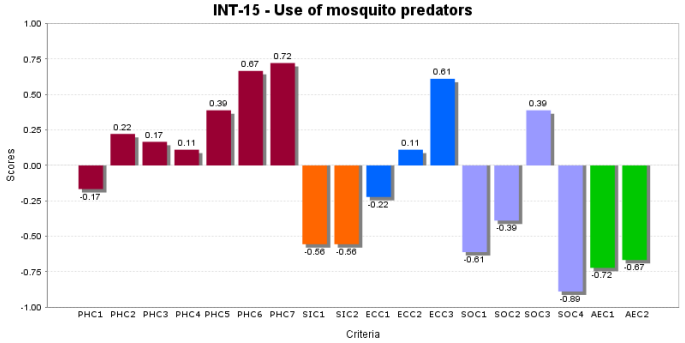


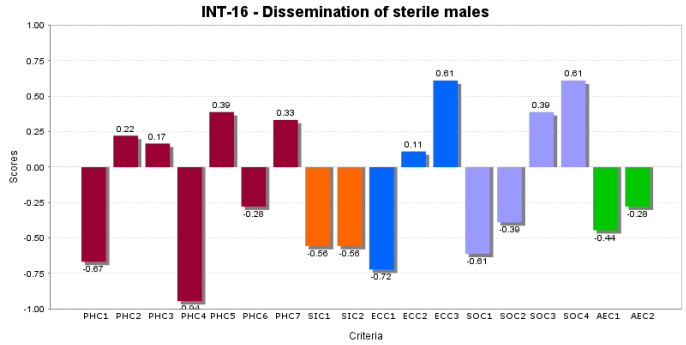

INT-11 - Modification of natural larval sites
Scores
Criteria
PHC1 PHC2 PHC3 PHC4 PHC5 PHC6 PHC7 SIC1 SIC2 ECC1 ECC2 ECC3 SOC1 SOC2 SOC3 SOC4 AEC1 AEC2

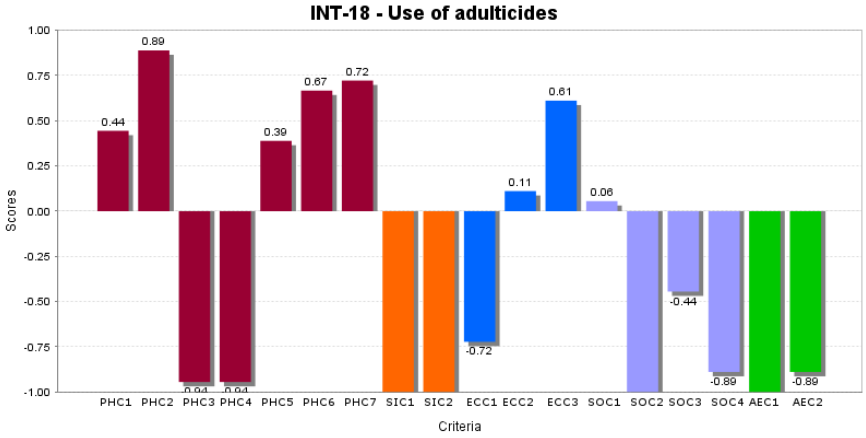

INT-12 - Modificaiton of man-made larval sites
Scores
Criteria
PHC1 PHC2 PHC3 PHC4 PHC5 PHC6 PHC7 SIC1 SIC2 ECC1 ECC2 ECC3 SOC1 SOC2 SOC3 SOC4 AEC1 AEC2

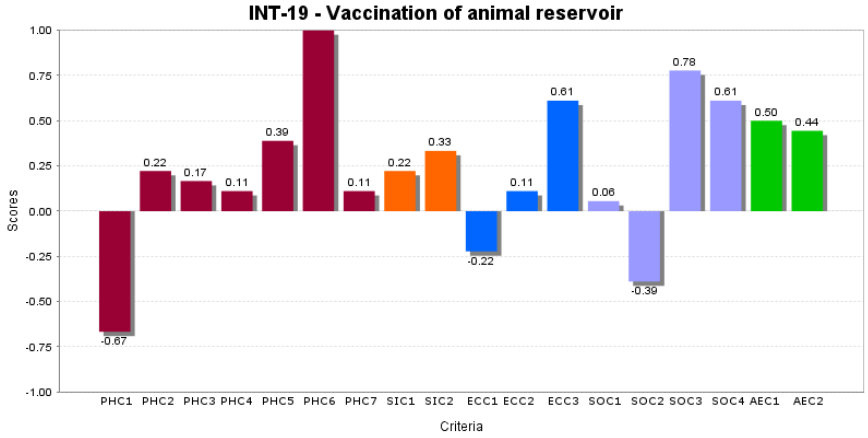

INT-13 - Use of parasites and pathogenic microorganisms
Scores
Criteria
PHC1 PHC2 PHC3 PHC4 PHC5 PHC6 PHC7 SIC1 SIC2 ECC1 ECC2 ECC3 SOC1 SOC2 SOC3 SOC4 AEC1 AEC2


INT-14 - Larvacides
Scores
Criteria
PHC1 PHC2 PHC3 PHC4 PHC5 PHC6 PHC7 SIC1 SIC2 ECC1 ECC2 ECC3 SOC1 SOC2 SOC3 SOC4 AEC1 AEC2


INT-15 - Use of mosquito predators
Scores
Criteria
PHC1 PHC2 PHC3 PHC4 PHC5 PHC6 PHC7 SIC1 SIC2 ECC1 ECC2 ECC3 SOC1 SOC2 SOC3 SOC4 AEC1 AEC2


INT-16 - Dissemination of sterile males
Scores
Criteria
PHC1 PHC2 PHC3 PHC4 PHC5 PHC6 PHC7 SIC1 SIC2 ECC1 ECC2 ECC3 SOC1 SOC2 SOC3 SOC4 AEC1 AEC2


INT-18 - Use of adulticides
Scores
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
0.44
0.89
-0.94
-0.94
0.39
0.67
0.72
0.11
-0.72
0.61
0.06
-0.44
-0.89
-0.89
PHC1 PHC2 PHC3 PHC4 PHC5 PHC6 PHC7 SIC1 SIC2 ECC1 ECC2 ECC3 SOC1 SOC2 SOC3 SOC4 AEC1 AEC2
Criteria


INT-19 - Vaccination of animal reservoir
Scores
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
-0.67
0.22
0.17
0.11
0.39
1.00
0.11
0.22
0.33
-0.22
0.11
0.61
0.06
-0.39
0.78
0.61
0.50
0.44
PHC1 PHC2 PHC3 PHC4 PHC5 PHC6 PHC7 SIC1 SIC2 ECC1 ECC2 ECC3 SOC1 SOC2 SOC3 SOC4 AEC1 AEC2
Criteria

Appendix 4 – Criteria included in the Manitoba Lyme model

Criteria Category	Criteria	Description	Indicator	Desired effect and direction	Scale
Public health criteria (PHC)	PHC-01 – Reduction in incidence of human cases	Measures effectiveness of action to reduce reported incidence (proportion of cases in the population) of human cases (symptomatic or not)	Reduction in human incidence of Lyme disease	Maximize reduction of human cases	0: Nil; 1: Low; 2: Moderate; 3: High
	PHC-02 – Reduction in entomological risk	Measures effectiveness of action to reduce entomological risk (infection rates and abundance of major vectors)	Reduction of vector density	Maximize entomological risk reduction	0: Nil; 1: Low (<33%); 2: Moderate (33-66%); 3: High (>66%)
	PHC-03 – Adverse health impacts	Measures the adverse (direct and indirect) effect of the action on human health (incl. vulnerable groups)	Severity of adverse health effects	Minimize adverse health effects	0: No effect or some positive effect; 1: Indirect negative effects on mental or social health; 2: Direct negative effects on physical health
	PHC-04 – Reduction of disseminated Lyme cases *	Measures the effectiveness of the action to reduce the incidence (proportion of cases in the population) of disseminated Lyme	Reduction in disseminated Lyme incidence	Maximize reduction of cases	0: Nil; 1: Global reduction of Lyme cases; 2: Reduction in disseminated Lyme cases
	PHC-05 – Increased case detection *	Measures the potential for an action to lead to an increase in the number of Lyme cases detected	Increased detection of Lyme cases	Maximize detection ability	0: No effect on case detection; 1: More cases detected;
Social impact criteria (SIC)	SIC-01 – Level of public acceptance	Measures the degree of acceptance of the action by the population and various stakeholders	Degree of acceptance of the population	Maximize social acceptance	0: Nil (this method will not be acceptable to the public); 1: Low (not easily accepted by the public); 2: Moderate (acceptable to public, but some opposed); 3: High (well received by general public)
	SIC-02 – Proportion benefitting	Measures the proportion of the population likely to benefit from the action	Number of people	Maximize the number benefitting	1: <25%; 2: 25-50%; 3: 50-75%; 4 : >75%
	SIC-03 – Level of public awareness *	Measures the degree of public awareness raised by the action	Degree of public awareness	Maximize public awareness	0: None, the intervention is aimed at tick density reduction only; 1: Low, the intervention is aimed at human populations but does not have an explicit objective to raise public awareness; 2: Moderate, the intervention may raise public awareness in a passive way; 3: High, the intervention aims to raise awareness in

Criteria Category	Criteria	Description	Indicator	Desired effect and direction	Scale
					an active way.
Animal and environmental health criteria (AEC)	AEC-01 – Impact on habitat	Measures the effect of the action on the environment	Level of risk to the environment	Minimize the environmental risk	Surface*Sensitivity*Intensity[2] Surf.: 1: Nil; 2: Small scale; 3: Large scale; Sens.: 1: Nil; 2: Land; 3: Water; 4: Land and water; Int.: 0: No effect or positive effect; 1: fence; 2: mowing; 3: Acaricides; 4: removal of vegetation; 5: Burning;
	AEC-02 – Impact on animal health	Measures the effect of the action on animal species (non-target species)	Level of health risk to animals	Minimize the animal health risk	Number*Species*Intensity[1] Nb.: 1: Nil; 2: Effect on one specific species; 3: Effect on several species; Spp.: 1: Nil; 2: Low valued species; 3: Highly valued species; Int.: 0: No effect or positive effects; 1: Morbidity; 2: Mortality
	AEC-03 – Reduction in incidence of animal cases *	Measures the effectiveness of the action to reduce the incidence of animal cases (dogs as indicator)	Reduction in animal incidence of Lyme disease	Maximize the reduction in incidence of animal cases	0: Nil; 1: Low; 2: Moderate; 3: High
Economic criteria (ECC)	ECC-01 – Cost to public sector	Estimates the cost to the public sector	Cost incurred by the government	Minimize the cost	0: Nil; 1: Low; 2: Moderate; 3: High
	ECC-02 – Cost to private sector	Estimates the cost to the private sector	Cost incurred by the private sector	Minimize the cost	0: Nil; 1: Low; 2: Moderate; 3: High
	ECC-03 – Savings to public sector *	Estimates the potential for economic saving to occur for public sector	Potential for economic savings	Maximize the savings	0: No savings; 1: Savings estimated to occur
	ECC-04 – Potential private sector economic benefit *	Estimates potential for economic benefit to occur for private sector	Potential for economic benefit	Maximize benefit	0: No economic benefit; 1: Potential economic benefit
Strategic and operational impact criteria (SOC)	SOC-01 – delay before results	Estimates the length of time between implementation of the action and the observation of desired effects	Estimated time delay between action and results	Minimize the delay	1: Days; 2: Weeks; 3: Months; 4 : Years

Criteria Category	Criteria	Description	Indicator	Desired effect and direction	Scale
	SOC -02 – Operational complexity	Estimates the operational complexity related to the implementation of the action	Level of operational complexity of the action	Minimize the level of operational complexity	1: Simple (minor institutional changes); 2: Intermediate (necessitates new hires); 3: Moderate (necessitate new work teams in one sector of intervention); 4: Complex (requires inter-sectoral/inter-institutional changes); 5: Very complex (necessitates creation of new structures or organizations)
	SOC -03 – Potential impact to organization's credibility	Estimates the potential for negative impacts to perceived credibility of the organization by the general public	Perceived credibility	Minimize conflicts	0: Nil (This action should have no negative impact or slight positive effect on organisation's perceived credibility); 1: Low (this action may have a weak adverse effect on organisation's perceived credibility); 2: Moderate (this action may have a moderate adverse effect on organisation's perceived credibility); 3: High (this impact may have a strong negative impact on organisation's perceived credibility)
	SOC -04 – Sustainability of effect *	Estimates the duration of efficiency of the action	Duration of effectiveness of the action	Maximize the duration of effectiveness	0: Nil; 1: low: must be reapplied frequently to obtain long term effect; 2: moderate – must be maintained sporadically for effect to occur, but effect sustainable in time; 3: excellent– once in place, effect is sustained without repeated efforts required to maintain
	SOC-05- Intra-regional coherence of strategy *	Estimates the coherence within the province	Coherence within the province	Maximize the coherence	0: Nil, not applicable province-wide; 1: Applicable province-wide
	SOC-06- Inter-regional coherence of strategy *	Estimates the coherence with neighbouring region strategies (Canadian provinces and US)	Coherence with regional strategies	Maximize the coherence	0: Nil, intervention not recommended by neighbouring authorities; 1: the intervention recommended by neighbouring authorities.

*** New criteria added in the Manitoba model**

Appendix 4 - Modifications made to Quebec Lyme disease evaluations for the Manitoban context

Action	Modifications	Interpretation
ALT-1 Exclude people from high-risk public areas	PHC-01 criteria increased from 1 to 2 PHC-03 criteria increased from 0 to 1 AEC-01 criteria decreased from 3 to 1 SIC-01 criteria decreased from 3 to 0 SIC-02 criteria decreased from 3 to 2 ECC-01 criteria increased from 0 to 1 SOC-01 criteria decreased from 2 to 1	Reduction in incidence of human cases of Lyme disease deemed to be moderately effective. Potential for adverse health effects increased from none to indirect negative effects on mental or social health Potential negative impact on habitat reduced from 3 to 1 Social acceptability reduced from high to nil Proportion benefitting reduced from 50-75% to 25-50% Cost to public sector increased from none to low Potential Delay before results reduced from weeks to days
ALT-3 Offer human Lyme vaccine	SIC-01 criteria decreased from 3 to 2 SIC-02 criteria increased from 3 to 4 ECC-02 criteria increased from 0 to 3 SOC-03 criteria decreased from 2 to 0	Social acceptability reduced from high to moderate Proportion benefitting increased from 50-75% to over 75% Cost to private sector increased from Nil to high Potential for negative impact on credibility reduced from moderate to nil.
ALT-4 Setup special Lyme disease diagnostic / treatment clinics	SIC-01 criteria decreased from 4 to 3 SOC-02 criteria decreased from 5 to 4 SOC-03 criteria decreased from 2 to 1	Social acceptance reduced from very high to high Operational complexity decreased from very complex to complex Potential for negative impact on credibility decreased from moderate to low
ALT-7 Carry out small scale landscaping	PHC-03 criteria decreased from 1 to 0 AEC-01 criteria decreased from 20 to 12 SIC-01 criteria decreased from 3 to 2 ECC-01 criteria increased from 1 to 2 SOC-02 criteria decreased from 4 to 3 SOC-03 criteria decreased from 2 to 1	Potential for adverse health effects decreased from indirect negative effects on mental health to no effect Potential impact on habitats reduced from 20 to 12 Social acceptability reduced from high to moderate Cost to public sector increased from low to moderate Operational complexity reduced from complex to moderate Potential for negative impact on credibility decreased from moderate to low
ALT-8 Large scale habitat modification	AEC-01 criteria decreased from 30 to 24 AEC-02 criteria decreased from 9 to 6 SIC-01 criteria decreased from 2 to 1 SIC-02 criteria increased from 1 to 2	Potential impact on habitats reduced from 30 to 24 Potential impact on animal health reduced from 9 to 6 Social acceptability decreased from moderate to low Proportion benefitting increased from less than 25% to 25-50%
ALT-9 Small scale acaricide application	AEC-02 criteria increased from 8 to 12 ECC-01 criteria increased from 1 to 2 ECC-02 criteria decreased from 1 to 0 SOC-02 criteria decreased from 4 to	Potential impact on habitat increased from 8 to 12 Cost to public sector increased from low to moderate Cost to private sector decreased from low to none Delay reduced from years to months

	3 SOC-03 criteria decreased from 3 to 2	Potential negative impact on credibility decreased from high to moderate
ALT-10 Large scale acaricide application	SIC-01 criteria decreased from 2 to 1 SIC-02criteria decreased from 4 to 2	Social acceptability reduced from moderate to low Proportion benefitting reduced from >75% to 25-50%
ALT-11 Desiccants / insecticidal soap	SIC-01 criteria decreased from 2 to 1 ECC-01 criteria increased from 1 to 2	Social acceptability reduced from moderate to low Cost to public sector increased from low to moderate
ALT-13 '4-poster' device	SIC-01 criteria decreased from 3 to 2 SIC-02 criteria increased from 1 to 2 SOC-03 criteria decreased from 2 to 1	Social acceptability reduced from high to moderate Proportion benefitting increased from <25% to 25-50% Potential negative impact on credibility decreased from moderate to low
ALT-14 Deer bait stations	PHC-01 criteria increased from 1 to 2 PHC-02 criteria decreased from 2 to 1 SIC-01 criteria decreased from 3 to 2 SIC-02 criteria increased from 1 to 2 ECC-01 criteria increased from 1 to 2 SOC-03 criteria decreased from 3 to 1	Reduction in incidence of human cases of Lyme disease increased from low to moderate Reduction in entomological risk reduced from moderate to low Social acceptability reduced from high to moderate Proportion benefitting increased from <25% to 25-50% Cost to public sector increased from low to moderate Potential negative impact on credibility reduced from high to low
ALT-15 'Damminix' devices	PHC-01 criteria increased from 0 to 1 SIC-01 criteria decreased from 3 to 2 SOC-03 criteria decreased from 2 to 1	Reduction in incidence of human cases of Lyme disease increased from nil to low Social acceptability decreased from high to moderate Potential negative impact on credibility reduced from moderate to low
ALT-16 Rodent bait boxes with fipronil	PHC-01 criteria increased from 0 to 1 PHC-02 criteria increased from 1 to 2 SIC-01 criteria decreased from 3 to 2 SOC-01 criteria increased from 3 to 4 SOC-03 criteria decreased from 2 to 1	Reduction in incidence of human cases of Lyme disease increased from nil to low Reduction in entomological risk increased from low to moderate Social acceptability decreased from high to moderate Delay increased from months to years Potential negative impact on credibility reduced from moderate to low
ALT-19 Deer exclusion via fencing	PHC-03 criteria increased from 0 to 1 SIC-01 criteria decreased from 3 to 2 SIC-02 criteria increased from 1 to 2 SOC-03 criteria decreased from 2 to 1	Potential for adverse health effects increased from none to indirect negative effects on mental or social health Social acceptability decreased from high to moderate Proportion benefitting increased from <25% to 25-50%

		Potential negative impact on credibility reduced from moderate to low
ALT-20 Deer hunting	PHC-01 criteria increased from 0 to 1 SIC-01criteria increased from 2 to 3 SOC-02 criteria decreased from 4 to 3 SOC-03criteria decreased from 3 to 2	Reduction in incidence of human cases of Lyme disease increased from nil to low Social acceptability increased from moderate to high Operational complexity reduced from complex to moderate Potential negative impact on credibility reduced from high to moderate
ALT-21 Deer culling	AEC-02 criteria decreased from 27 to 18 SIC-01 criteria decreased from 1 to 0 SOC-02 criteria increased from 4 to 5 SOC-03 criteria decreased from 4 to 3	Potential impact on animal health reduced from 27 to 18 Social acceptability reduced from low to nil Operational complexity increased from complex to very complex Potential negative impact on credibility reduced from very high to high
ALT-22 Status quo (baseline)	SOC-03 criteria decreased from 1 to 0	Potential negative impact on credibility reduced from low to nil

Appendix 5 - Multi-Stakeholder Decision Aid for Improved Prioritization of the Public Health Impact of Climate Sensitive Infectious Diseases*

Valerie Hongoh[1], Pascal Michel[1,3], Pierre Gosselin[4,5], Karim Samoura[1,6], André Ravel[2], Céline Campagna[4,7], Hassane Djibrilla Cissé[8] and Jean-Philippe Waaub[9]

[1] The Research Group on Epidemiology of Zoonoses and Public Health (GREZOSP), Faculty of Veterinary Medicine, Université de Montréal, 3200 rue Sicotte, C.P. 5000, Saint-Hyacinthe, QC J2S 7C6, Canada

[2] Department of Pathology and Microbiology, Faculty of Veterinary Medicine, Université de Montréal, 3200 rue Sicotte, C.P. 5000, Saint-Hyacinthe, QC J2S 7C6, Canada

[3] National Microbiology Laboratory at Saint-Hyacinthe, Public Health Agency of Canada, 3200 rue Sicotte, C.P. 5000, Saint-Hyacinthe, QC J2S 7C6, Canada

[4] Institut National de Santé Publique du Québec (INSPQ), 945 Avenue Wolfe, Québec, QC G1V 5B3, Canada

[5] Ouranos, Consortium on Regional Climatology and Adaptation to Climate Change, Montreal, QC H3A 1B9, Canada

[6] Université Aube Nouvelle, Quartier 1200 Logement, 06 B.P.: 9283, Ouagadougou, Burkina Faso

[7] Department of Social And Preventive Medicine, Université Laval, 2325 Rue de l'Université, Québec, QC G1V 0A6, Canada

[8] Urban Safety and Sustainable Development, Bureau of Environmental Evaluation and Impact Studies of the Ministry of Environment, Niamey B.P.: 578, Niger

[9] Group for Research in Decision Analysis (GERAD), 3000, Côte-Sainte-Catherine Rd., Montreal, QC H3T 2A7, Canada

*Article published: Hongoh, V, Michel, P, Gosselin, P, Samoura, K, Ravel, A, Campagna, C, Cissé, H, Waaub J-P: Multi-Stakeholder Decision Aid for Improved Prioritization of the Public Health Impact of Climate Sensitive Infectious Diseases. *Int. J. Environ. Res. Public Health* 2016, 13(4): doi:10.3390. Available: http://www.mdpi.com/1660-4601/13/4/419/html

International Journal of
Environmental Research and Public Health

MDPI

Article

Multi-Stakeholder Decision Aid for Improved Prioritization of the Public Health Impact of Climate Sensitive Infectious Diseases

Valerie Hongoh [1,2,*], Pascal Michel [1,3], Pierre Gosselin [4,5], Karim Samoura [1,6], André Ravel [2], Céline Campagna [4,7], Hassane Djibrilla Cissé [8] and Jean-Philippe Waaub [9]

1 The Research Group on Epidemiology of Zoonoses and Public Health (GREZOSP), Faculty of Veterinary Medicine, Université de Montréal, 3200 rue Sicotte, C.P. 5000, Saint-Hyacinthe, QC J2S 7C6, Canada; pascal.michel@phac-aspc.gc.ca (P.M.); karim.samoura@u-auben.org (K.S.)
2 Department of Pathology and Microbiology, Faculty of Veterinary Medicine, Université de Montréal, 3200 rue Sicotte, C.P. 5000, Saint-Hyacinthe, QC J2S 7C6, Canada; andre.ravel@umontreal.ca
3 National Microbiology Laboratory at Saint-Hyacinthe, Public Health Agency of Canada, 3200 rue Sicotte, C.P. 5000, Saint-Hyacinthe, QC J2S 7C6, Canada
4 Institut National de Santé Publique du Québec (INSPQ), 945 Avenue Wolfe, Québec, QC G1V 5B3, Canada; pierre.gosselin@inspq.qc.ca (P.G.); celine.campagna@inspq.qc.ca (C.C.)
5 Ouranos, Consortium on Regional Climatology and Adaptation to Climate Change, Montreal, QC H3A 1B9, Canada
6 Université Aube Nouvelle, Quartier 1200 Logement, 06 B.P.: 9283, Ouagadougou, Burkina Faso
7 Department of Social And Preventive Medicine, Université Laval, 2325 Rue de l'Université, Québec, QC G1V 0A6, Canada
8 Urban Safety and Sustainable Development, Bureau of Environmental Evaluation and Impact Studies of the Ministry of Environment, Niamey B.P.: 578, Niger; hd.cisse@gmail.com
9 Group for Research in Decision Analysis (GERAD), 3000, Côte-Sainte-Catherine Rd., Montreal, QC H3T 2A7, Canada; waaub.jean-philippe@uqam.ca
* Correspondence: valerie.hongoh@umontreal.ca; Tel.: +1-450-773-8521

Academic Editor: Paul B. Tchounwou
Received: 9 February 2016; Accepted: 7 April 2016; Published: 12 April 2016

Abstract: The effects of climate change on infectious diseases are an important global health concern and necessitate decisions for allocation of resources. Economic tools have been used previously; however, how prioritization results might differ when done using broader considerations identified by local stakeholders has yet to be assessed. A multicriteria decision analysis (MCDA) approach was used to assess multi-stakeholder expressed concerns around disease prioritization *via* focus groups held in Quebec and Burkina Faso. Stakeholders weighted criteria and comparisons were made across study sites. A pilot disease prioritization was done to examine effects on disease rankings. A majority of identified criteria were common to both sites. The effect of context specific criteria and weights resulted in similar yet distinct prioritizations of diseases. The presence of consistent criteria between sites suggests that common concerns exist for prioritization; however, context-specific adjustments reveal much regarding resource availability, capacity and concerns that should be considered as this impacts disease ranking. Participatory decision aid approaches facilitate rich knowledge exchange and problem structuring. Furthermore, given multiple actors in low- and middle-income countries settings, multi-actor collaborations across non-governmental organizations, local government and community are important. Formal mechanisms such as MCDA provide means to foster consensus, shared awareness and collaboration.

Keywords: participatory decision aid; multi-criteria decision analysis; infectious disease prioritization