MASTER
ECOLOGIE-BIODIVERSITE
SPECIALITE MALADIES TRANSMISSIBLES : ENVIRONNEMENT, DYNAMIQUE
PARCOURS SAEPS
SANTE ANIMALE ET EPIDEMIOSURVEILLANCE DANS LES PAYS DU SUD

RAPPORT DE STAGE DE SECONDE ANNEE

DEVELOPING A FRAMEWORK FOR ASSESSING WILDLIFE HEALTH

A model for wildlife health intelligence for use in the Sri Lanka Wildlife Health Centre

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Organisme et pays : CCH, CCWHC, CANADA
Période du stage : 18 mars au 30 août 2013
Date de soutenance : 12-13 septembre 2013

Année universitaire 2013-2014

ABSTRACT & KEY WORDS

The global health system is facing the challenge of emerging infectious diseases (EIDs) within wildlife. Forecasting the risks of emerging diseases in wildlife requires an intelligence-based approach. We propose a conceptual framework and assess the theoretical feasibility of a wildlife health intelligence program for the Sri Lanka Wildlife Health Centre (SLWHC). Sri Lanka is a tropical lower middle-income country located within the geographic area considered at the highest risk for the infectious disease emergence. In 2011, Sri Lanka created the SLWHC to improve the nation's ability to monitor and manage diseases from wildlife that present a risk to public health as well as diseases affecting wildlife conservation. Literature review and key informant interviews were conducted to identify the theoretical requirements for wildlife health intelligence. Expert opinion was solicited to assess the feasibility of implementing a health intelligence system in a high-income setting (British Columbia, Canada). A second literature review and interviews were used to determine if the theoretical framework assessed to be feasible in a higher income setting could be applied in a lower resource setting (Sri Lanka). The study revealed that wildlife health intelligence is a generally feasible and desirable approach but it could not be achieved without coordination in data collection, adequate capacity, and funding. In the case of the SLWHC, we concluded that a health intelligence approach was desirable but currently not achievable. Several recommendations are provided but the priority should be put on raising the national institutions and population awareness about the existence of the SLWHC and the need to report wildlife health events, improving communication between the public, academia and government, and building partnership and collaboration between national infrastructures.

Key words : surveillance ; intelligence ; emerging infectious disease ; animals ; health ; health intelligence ; infectious disease outbreak ; wildlife ; Sri Lanka ; Sri Lanka Wildlife Health Centre

RESUME ET MOTS-CLES

Les maladies infectieuses émergentes constituent un des défis du système de santé mondial actuel. Prévoir les risques d'émergence de maladies au sein de la faune sauvage nécessite une nouvelle approche basée sur la notion anglophone d'intelligence. Nous proposons un cadre conceptuel et évaluons la faisabilité théorique d'un système d'intelligence pour la santé de la faune sauvage pour le Centre sri lankais pour la santé de faune (SLWHC). Le Sri Lanka est un pays tropical classé dans la tranche inférieure des pays à revenus intermédiaires et situé dans la zone géographique à risque majeur pour l'émergence de maladies infectieuses. En 2011, le Sri Lanka a créé le SLWHC afin d'améliorer la capacité nationale à surveiller et à gérer les maladies provenant de la faune sauvage et présentant un risque aussi bien pour la santé publique que pour la conservation de la faune. Un examen de la littérature existante et des interviews d'informateurs clés ont été conduits pour identifier les exigences théoriques d'une intelligence pour la santé de la faune. L'opinion d'experts a été sollicitée pour évaluer la faisabilité de la mise en place d'un système d'intelligence pour la santé dans un pays à revenu élevé (Colombie-Britannique, Canada). Une seconde étude de la littérature et des interviews ont été réalisées pour déterminer si le cadre théorique évalué comme faisable dans les pays à revenu élevé pouvait être appliqué dans un pays à revenu inférieur (Sri Lanka). L'étude révèle que l'intelligence pour la santé de la faune est en général une approche possible et désirable mais qui ne peut être réalisée sans l'existence de coordination dans la collecte des données, des capacités adéquates et de financement. Dans le cas du SLWHC, une approche via l'intelligence pour la santé est désirable mais non réalisable actuellement. Plusieurs recommandations sont émises mais la priorité devrait être portée sur la sensibilisation des institutions nationales et de la population à l'existence du SLWHC et à la nécessité de rapporter les évènements en relation avec la faune sauvage, améliorer la communication entre le public, les institutions académiques et le gouvernement, et la création de partenariats et de collaboration entre les infrastructures nationales.

Mots clés : surveillance ; intelligence ; maladies infectieuses émergentes ; animaux ; Santé ; faune sauvage ; Sri Lanka ; Centre sri lankais pour la santé de la faune

ABBREVIATIONS

BC : British Columbia
Bd : *Batrachochytrium dendrobatidis*
CCH : Centre for Coastal Health
CFIA : Canadian Food Inspection Agency
DAPH : Department of Animal Production and Health
DWC : Department of Wildlife Conservation
CCWHC : Canadian Cooperative Wildlife Health Centre
CDC : Center for Disease Control and Prevention
CNPHI : Canadian Network for Public Health Intelligence (RCRSP in French)
CO : Conservation officer
EID : Emerging Infectious Disease
EIS : Epidemic Intelligence Service
FAO : Food and Agriculture Organization of the United Nations
FBI : Federal Bureau of Investigation
FLNRO : Ministry of Forests, Lands and Natural Resource Operations
FVMAS : Faculty of Veterinary Medicine and Animal Science (University of Peradeniya)
FVS : Field Veterinary Surgeon
FWV : Field Wildlife Veterinarian
GAO : United States General Accounting Office
GPHIN : Global Public Health Intelligence Network (RMISP in French)
NGO : Non-Government Organization
IDRC : International Development Research Centre
LMIC : Low and Middle Income Countries
OIE : World Organisation for Animal Health
RCRSP : Réseau Canadien de Renseignements sur la Santé Publique
RMISP : Réseau Mondial d'Information en Santé Publique
SLWHC : Sri Lanka Wildlife Health Centre
UNESCAP : United Nations Economic and Social Commission for Asia and the Pacific
VCI : Veterinary Investigation Center
VIO : Veterinary Investigation Officer
vs : versus

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ACKNOWLEDGEMENTS

I would like to express my deep gratitude to Dr. Frederick A. (Ted) Leighton and Dr. Craig Stephen, my research supervisors, for their patient guidance, enthusiastic encouragement and useful critiques of this research work.

I would like to thank Dr. Eric Etter for his support during this work.

I would like to thank Dr. Helen Schwantje and Cait Nelson for their participation and patience in the elaboration of the questionnaire and thank all the participants to questionnaire as well. This study would not have been possible without you.

My grateful thanks are also extended to Jennifer Dawson-Coates for sharing her experience about Sri Lanka, her help and continuous support during my stay.

I wish to thank Dr. Sam Daniels who gave me useful information about the Sri Lanka governmental organization.

I would like to thank Dr. Carl Ribble, Dr. Tyler Stitt and Stefan Iwasawa for their support and for letting me participating in other projects.

I would like to thank all the members from the International Centre for Sturgeon Studies and my new Canadian friends for their warm welcome.

And finally, I would like to thank my family for their support during my studies.

I. INTRODUCTION

Between 1940 and 2004, close to 60 percent of emerging infectious diseases that have been reported in global human population have been zoonoses and close to 75 percent of them have arisen in wildlife (Jones *et al.*, 2008). Geographic areas characterized by high populations of people, domestic animals and wildlife, and rapidly changing environmental conditions have been associated with higher probabilities for emergence of important human and animal infectious diseases. Densely populated tropical and sub-tropical countries have been judged to be the highest risk targets (Woolhouse and Gowtage-Sequeria, 2005). This region is in the zone where investment in national capacity for early detection of new or newly important pathogens is predicted to have the greatest global impact (Valeix *et al.*, 2011).

Sri Lanka is a densely populated island with about 21 million people (Word Bank, 2011) that has many of the features of a country at high risk for disease emergence. Like many of tropical low and middle income countries (LMICs), Sri Lanka does not currently have adequate capacity in wildlife health research to rapidly detect, assess and respond to emerging risks at the human-wildlife health interface or to build capacity to prevent such risks or help affected populations recover from disease outbreaks. Since 2005, Sri Lanka and Canada have been collaborating on several veterinary and public health programs (Di Ruggiero *et al.*, 2006 ; Munasinghe *et al.*, 2008 ; Robertson and Nelson, 2010 ; Robertson *et al.*, 2010 ; Stephen and Daibes, 2010). In 2008, the Sri Lankan Government solicited assistance from the Canadian Cooperative Wildlife Health Centre (CCWHC) (Saskatoon, Saskatchewan) and the Centre for Coastal Health (CCH) (Nanaimo, British Columbia (BC)) to enhance national capacity in wildlife surveillance. Valeix *et al.* (2011) conducted a feasibility study for the establishment of a national wildlife health centre in Sri Lanka and concluded that improvements in education, specialist training, diagnostic facilities, transportation of people and samples and central coordination were needed. In 2011, Sri Lanka created the Sri Lanka Wildlife Health Centre (SLWHC) modeled on the CCWHC. The SLWHC is co-managed by the Faculty of Veterinary Medicine and Animal Science (FVMAS) (University of Peradeniya), the Department of Animal Production and Health (DAPH), the Department of Wildlife Conservation (DWC) and the Ministry of Health. It was established to provide an official enabling political environment and governance structure within which wildlife health research capacity and programs can be developed with a goal of preventing emerging disease risks at the wildlife-human interface by fostering healthy wildlife and positive human-wildlife interactions.

No universal definition of wildlife health has been established. The Ottawa Charter for Health Promotion (Anonymous, 1984) defined human health as :

"The extent to which an individual or group is able to realize aspirations and satisfy needs, and to change or cope with the environment. Health is a resource for everyday life, not the objective of living ; it is a positive concept, emphasizing social and personal resources, as well as physical capacities."

While this definition was made for people, it applies to animals if we consider animal health as a product of how animals interact with other animals, their environment and people. To monitor health, it is important to observe health outcomes like nutritional status, reproduction, longevity and diseases, but it is equally important to be aware of change in the factors that affect animal vulnerability to harm and ability to cope with stressors of changes (called health determinants) as well as to track possible hazards that could affect their health. Health determinants can be found in the physical and social environments of animals (e.g. habitat, food, harassment, hunting). Determinants of health may be inherent parts of the animals or their ecology as well as derived from how people interact with or affect animals' vulnerability or resilience.

Historically, wildlife health programs have tracked death and diseases ; often assuming health to be the absence of disease. Programs to detect health problems were, therefore, largely focussed on these outcomes, resulting in the need for wildlife health programs to be reactive to adverse outcomes rather than proactive and preventive in nature. In addition, pathogen-centred programs often failed to provide information that was needed to assess how discovery of a disease or infection in wildlife affected risk to other species, including people (Stephen, 2013). In this project, we tried to develop a new framework for assessing wildlife health and for generating the additional information needed to understand the nature of risk posed by the detection or discovery of a disease in wildlife. In addition to early detection of hazards, we considered if a program could also generate information to achieve anticipation and prediction, to facilitate early response to risk in order to prevent disease or other adverse effects. Indeed, multiple interacting hazards and threats to wildlife are growing (urbanization, deforestation, desertification, climate change, pollution, transportation of pathogens etc.) and, at the same time, resources to track wildlife health outcomes and our resources and ability to act are limited. We need a way to identify priority problems, species, locations and strategies in order to make the biggest impact on the most vulnerable populations. Health intelligence appeared to be the best choice for a model because "Intelligence allows anticipation or prediction of future situations and circumstances, and it informs decisions by illuminating the differences in available courses of action" (Anonymous, 2007). The Collins dictionary defines health intelligence as : " Health Intelligence is responsible for capturing and utilizing knowledge to support decision-making to improve the health of the population". A focused ethnographic study of Sri Lankan government field veterinarians' decision making about diagnostic laboratory submissions and perceptions of surveillance (Sawford *et al.*, 2012) previously conducted was used as a foundation for this study to understand the Sri Lankan approach on animal health issues.

The purpose of the study was to develop a theoretical wildlife health intelligence system based on literature and to assess the feasibility of implementing wildlife health intelligence for the SLWHC.

II. MATERIALS AND METHODS

The study was conducted in four phases. Firstly, a scoping literature review was done to establish a definition of wildlife health intelligence, to distinguish a health

intelligence system from disease surveillance, to determine how wildlife could benefit from an intelligence system and to identify what elements or features are needed to develop such a system. Secondly, we developed a table of criteria and indicators that could, in theory, be tracked in a health intelligence system. Then, British Columbian key informants involved in fish and wildlife management were interviewed or surveyed to assess the feasibility for a wildlife health intelligence program to be a part of the British Columbian fish and wildlife management. Finally, a second scoping literature review was done to identify the main points to consider when contemplating adapting the theoretical framework for wildlife health intelligence to low and middle income countries and Sri Lanka in particular.

A. Wildlife health Intelligence literature review

Wildlife health intelligence is not a term found in literature and is rarely discussed in animal health. Therefore, I undertook a broader literature review to identify the features of a health intelligence system. A review of primary and secondary literature was conducted by using Pubmed, Web of Knowledge and Google. A mix of the following phrases was used : intelligence, health, military intelligence, epidemic intelligence, early warning system, bioterrorism, disease surveillance, emerging infectious diseases (EIDs), wildlife, herd health.

I retrieved and reviewed all of the papers. There was not an attempt to assess the quality of the papers. The purpose of a scoping literature review is to "map" the literature to find common themes. It is more appropriate for use in broad topics that require examining of studies with different methods, design and context (Arksey and O'Malley, 2005). Articles, reports and websites were considered. English, French and Spanish languages titles and abstracts were considered and papers selection was done if they satisfied at least one of the following criteria : (i) they reviewed or synthetized knowledge about the subjects of intelligence, intelligence systems, health monitoring, disease surveillance, health assessment, emerging infectious diseases, early warning system, wildlife monitoring, wildlife management, and herd health programs ; (ii) they provided information about intelligence principles and on intelligence system construction ; (iii) they defined and/or detailed military or epidemic intelligence ; or (iv) they compared health assessment and disease surveillance. Comparison between health intelligence and disease surveillance was completed on *table 2*. Commons goals, objectives and components of intelligence systems were considered as intelligence system features. The results were presented with diagrams *(Figures 1 and 3)*.

B. Health criteria for data collection

To identify potential indicators of wildlife health, I began by using a generic model for dairy herd health and human population health. Then, I used expert opinion by interviewing veterinarians with expertise in disease surveillance and wildlife (Dr. Craig Stephen, Dr. Ted Leighton) and wildlife health management (Dr. Helen Schwantje) as well as a wildlife biologist who works in the area of wildlife health (Cait Nelson). From these conversations, I adapted dairy herd health attributes to

wildlife, separating variables into broader classes of social, physical or environmental determinants of health or health outcomes (*Table 3*).

C. Key informants interviews

1. Rationale for key informant interviews

The results of a scoping literature review can often be enhanced with additional expert consultation (Arksey and O'Malley, 2005). As wildlife health intelligence is a new concept for fish and wildlife management in Sri Lanka or British Columbia, exploratory interviews with experts were needed. The goal of the interviews was to gather information on the national or local people or organizations that potentially might be involved in the collection of data for wildlife health intelligence and to gather expert opinions on the best means to analyze these data and communicate their significance. Given the need to collect data in a short period of time and from wide range competency domains, key informant interviews were the dedicated tool. An advantage in using key informants is, because informants were chosen for their thorough knowledge of their own wildlife health related system, they were likely to be aware of the relationships and hierarchy issues that can exist and so better placed to evaluate the practicality of potential actors involvement (Dvorak, 1992).

2. Choice of key informants

Key informants were defined as people with a special expertise in a domain related to at least one of the health determinants or outcomes previously identified (*Table 3*). The first key informants to be involved were the wildlife veterinarian who runs the BC Ministry of Forests, Lands and Natural Resource Operations (FLNRO) Wildlife Management Branch (Canada) and her colleague a wildlife health biologist and the director of the CCWHC. Then, a snowball sampling was conducted to identify at least 6 to 12 key informants. This number of informants has been shown to achieve saturation of new concepts revealed by key informant interviews in qualitative research if the participants evolve in a fairly homogenous environment (Guest *et al.*, 2006). Data saturation is the point in data collection and analysis when new information produces little or no additional knowledge.

3. Overview of key informant questionnaire

A standardized format was developed to guide key informant interviews in BC (*Appendix 1*). Its general framework is presented into *Table 1*. Questions were either closed or open-ended. Each questionnaire was sent with an introduction to explain the context, the notion of wildlife health intelligence and the purpose of the questionnaire (*Appendix 2*). Informants filled in the questionnaire on their own and returned for analysis. I was available to answer their questions or provide clarifications necessary to help the informants complete the task.

Topics and questions themes
Participants
Job responsibility : wildlife/humans/ domestic animals/public health…
Employer : national/federal/provincial government, university, private, NGO…
Job location
Access to internet
Role : decision-maker, health provider, conflict manager, researcher
Awareness of current programs on wildlife management, conservation, surveillance
Awareness of health intelligence
Vision on purpose of health intelligence
Data collection
Completeness of *Table 3*
Who or what agency might have data (now or in the future) or help with data collection for each of the categories of health data listed in *Table 3*
Top 5 information sources that are most reliable, feasible to collect and consistently collectable (repeatable) in *Table 3*
Limitations to reliable and repeatable data collection
Three essentials health determinants or outcomes that should be tracked in *Table 3* and reasons for their selection
First priority species to benefit from wildlife health intelligence and reasons
Data analysis and application
Skills and capacity for data analysis function : meeting with all principles stakeholders and potential participants, mapping, making graphics to follow factors evolution, statistics for indicator change detection, modelling
Additional data analysis function
Gaps and needs
Gaps for the implementation of a wildlife health intelligence
Needs to close these gaps within 1-2 years
Needs to close these gaps within 5-10 years

Table 1: Frame of the wildlife health intelligence key informant questionnaire

D. Adaptation to LMICs literature review

The previous literature review method was followed with the addition of the following words: intelligence, LMIC, adaptation, health, wildlife, EID. A focus was also made on some key documents provided by Dr. Craig Stephen (Saint Louis, 2012 ; FAO, 2011 ; Leighton *et al.*, 2012 ; GAO, 2011 and OIE, 2011).

III. RESULTS

A. Health Intelligence versus Disease Surveillance

Intelligence can be defined in several different ways (Legg and Hutter, 2007) without universal consensus. It is considered either as a biological or an organizational concept. Organizational intelligence is mentioned as a pooling of

biological intelligence. The British organizational intelligence approach tends to equate intelligence with information whereas the American view, used in this study, defines intelligence as the sum of information and analysis. Both the British and American approaches emphasize the use of intelligence to support proactive, predictive decision-making (Cox, 2009).

Intelligence is a product and a process resulting from timely collecting and analyzing data in the right way in order to make them understandable and usable for future decision-making. Intelligence results from a cognitive hierarchy (*Figure 1*) (Cox, 2009). Raw data constitute the bottom of this hierarchy. Processing and analyzing raw data generate information. Then, by combining multiple types of information, some trends can be identified (cognition) and knowledge created. Expert understanding and judgment of the context, in which the knowledge is generated, helps to provide understanding of the significance of the new knowledge. To develop intelligence that can be used to inform decisions, future probabilities and scenarios are taken into account.

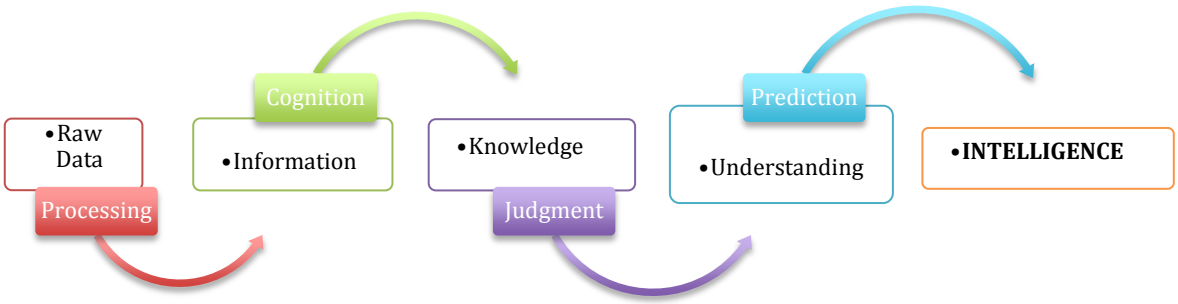

Figure 1: Intelligence: a cognitive hierarchy (modified from Cox, 2009)

The intelligence approach was first developed for the military after the Pearl Harbour surprise attack. "The United-States Government Federal Bureau of Investigation (FBI) and the other organizations that make up the U.S. Intelligence Community use the term "intelligence" in three different ways :

- Intelligence is a **product** that consists of information that has been refined to meet the needs of policymakers.

- Intelligence is also a **process** through which that information is identified, collected, and analyzed.

- And intelligence refers to both the individual **organizations** that shape raw data into a finished intelligence product for the benefit of decision makers and the larger **community** of these organizations. " (FBI website)

The purpose of military intelligence is to "watch and monitor all possible sources of threats and transform it into valuable intelligence content for implementing military operational activities" (Liao *et al.*, 2003). In 1951, the Epidemic Intelligence Service

(EIS) Program was created by the Center for Disease Control and Prevention (CDC), Atlanta, Georgia as a training program and for the public health practice of epidemiology (Thacker *et al.*, 2001). It was the first time "intelligence" had been used in health related sector. More recent bioterrorism threats were the inspiration to incorporate threat detection into public health programs. On October 2001, the United-States experienced a biological attack causing 22 anthrax cases, including 5 deaths. *Bacillus anthracis* spores had been intentionally distributed through the postal system (Hughes and Gerberding, 2002, Jernigan *et al.*, 2002). In this context of EIDs, the need to improve the ability to forecast risk and thus act to prevent EIDs or deploy resources in highest risk locations motivated the search for new ways to track health threats. To meet this purpose, numerous web-based biosecurity intelligence systems (Lyon *et al.*, 2012) and epidemic intelligence systems (Yde *et al.*, 2012) have been developed.

Other intelligence approaches had been developed. The most commonly known is likely to be artificial intelligence ("intelligence artificielle" in French) even if it does not refer to organizational but rather individual intelligence. It is defined as the study of the modeling of human mental functions by computer programs (Collins English Dictionary). Until now, additional existing organizational intelligence are emotional intelligence ("intelligence émotionnelle" in French) (Chanlat, 2003 ; Slovey and Mayer, 1990), epidemiological intelligence ("intelligence épidémiologique" in French) (Buton, 2006) and business intelligence ("intelligence économique" in French) (Pautrat and Delbecque, 2009). However, health intelligence remains quite an unexplored domain.

We found the term "health intelligence" a few times only in our scoping literature review. On one hand, some information management firms like Health Intelligence™ use this expression in their company name only in order to emphasize their target ; the health management services. On the other hand, the Public Health Agency of Canada introduces networks like the Canadian Network for Public Health Intelligence (CNPHI) or the Global Public Health Intelligence Network (GPHIN) (Public Health Agency of Canada website). These networks are secure Internet-based 'early warning system' whose aim is to detect potential health threats by gathering verified and relevant unverified information on disease outbreaks and other public health events by monitoring media sources. The GPHIN is a unique multilingual system working with six languages, namely, Arabic, Chinese, English, French, Russian and Spanish. This is one of the most reliable and efficient global early warning system. It was proven to detect a signal of an outbreak on average 3 months and 14 days after the first case (Rotureau *et al.*, 2007).

Two main reasons can explain why the expression "health intelligence" is rarely observed. First, it is a fairly new concept. Second, "intelligence" originated from America and when non-English speaking countries try to translate this notion, the word "intelligence" is not necessarily strictly translated. For example, as military intelligence is translated into "renseignements militaires" in French, the CNPHI becomes the réseau canadien de renseignements sur la santé publique (RCRSP) and the GPHIN is the Réseau mondial d'information en santé publique (RMISP). "Renseignements" and "information" are synonyms but not fully equal as intelligence.

The Collins Dictionary proposes this definition : “Health Intelligence is responsible for capturing and utilizing knowledge to support decision-making to improve the health of the population.” But, based on the overview of existing types of intelligence, I added some details to this definition. Health intelligence may be defined as the appropriate way to collect, analyze, interpret and timely report information in order to make it usable for decision-makers to improve health of the population. Data and information are wide-ranging, and are collected from different local or national scales and from numerous sources such as research papers, grey literature, federal and provincial agencies or non-for government organizations (NGOs). By collecting more diverse information, the intelligence-based system succeeds in early warning about a potential threat for the population health (Yde *et al.*, 2012).

Health, and wildlife health in particular, could be considered as the ability to cope with challenges (disease or environment), adapt and recover (resilience) to maintain a state of balance (sustainability) (Deem *et al.*, 2008 ; Hanisch *et al.*, 2012). Until now, most health monitoring programs have been focus on diseases surveillance. The British Columbian Ministry of Health defines disease surveillance as the ongoing, systematic collection, analysis, interpretation and timely dissemination of data to the appropriate audiences for public health action, including disease prevention, health promotion, program planning and evaluation (Anonymous, 2006). This laboratory-based surveillance is rather an *a posteriori* method that aims at tracing the origin and the spread of the disease in order to implement policy to stop its progress. Disease surveillance often relies on statistical analyses to determine when something is changing. But, the lack of capacity to sample, follow and track wildlife creates sampling biases and makes statistical analysis questionable (Stephen, 2013). Comparison between health intelligence and disease surveillance has been summed up in *Table 2*.

Characteristic	**Health Intelligence**	**Disease Surveillance**
Person	Groups	Individuals or Groups
Place	Local or Small Geographic Area	Varying scale
Time	Months to decades	Hours to months
Factors	All diseases, conditions, health determinants (environmental, social), health risk, health status	Mainly communicable diseases, but also risk behaviors, injuries and some chronic diseases
Anticipate “clusters” in either space or time	Yes	Yes
Focus	Long-term planning	Detection/Reactive
Data Collection	Multiple methods and sources including those outside of the health sector	Directly from client or physicians or veterinarians or indirectly from health services and via disease registries
Analysis and interpretation of data	Small numbers not utilized	Individuals cases analyzed and aggregated as appropriate
Dissemination of information	Broad: From health professionals to researchers, policy makers, program planners, public	Narrow and broad: * Individuals case information between health care providers and public health staff * Aggregate data interpreted and disseminated to those with a need to know

Table 2: Comparison between health intelligence and disease surveillance (modified from Anonymous, 2006)

So extrapolating from Anonymous (2006), I concluded that intelligence differs from surveillance in 3 main ways : (1) it collects information not only on pathology and etiologies but also on risks and capacities of populations to deal with environmental change ; (2) it is interested in health as opposed only to disease and (3) the goal of health intelligence is to protect and promote health by early actions in advance of harm while the goal of surveillance is early detection of harms to quickly minimize their effects. Health intelligence and surveillance are related and complementary activities (*Figure 2*).

Understanding the meaning of a newly discovered pathogen or problem requires additional contextual information delivered by health intelligence. The lack of baseline information about wildlife, and in particular fish (Ward and Lafferty, 2004), prevents interpreting and making reliable conclusions about the patterns and impacts of diseases. Laboratories often fail to acquire relevant contextual information about EIDs previously unknown to forecast the real risk for human or animals (Sawford *et al.*, 2011). Extra information about wildlife populations, interaction of people with the affected wildlife and interaction of agriculture with wildlife is often required to assess the nature of risk associated with a wildlife disease event.

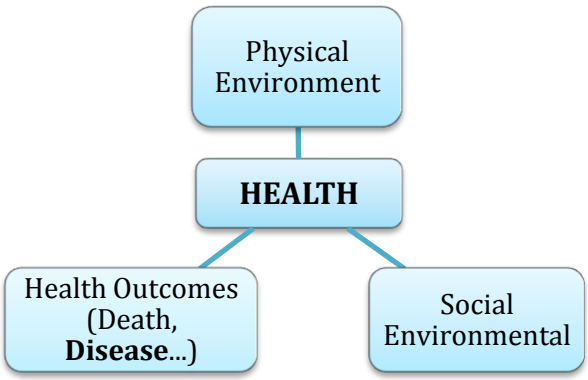

Figure 2: Disease as a component of health

In addition to preventing wildlife and human population from diseases, wildlife health intelligence could be assimilated with long-term wildlife conservation program. Indeed, Deem *et al.* (2008) declared :

"In fact, one way to view the core objective of any conservation program is the intention to ensure healthy wildlife populations and ecosystems, without compromising the health of humans. In turn, the health of these three components ; wildlife, ecosystems, and humans are increasingly dependent on conservation management measures."

Based on this overview, I can conclude that the underlying purpose of a wildlife health intelligence program is to gather and combine information on (i) hazards to animal health, (ii) health outcomes; (iii) data on factors affecting animal exposure or vulnerability and (iv) information on factors affecting animals ability to recover from

harms of stressors in order to characterize a population's health status and hopefully inspire action to protect animal health and public health before severe impacts are detected (Stephen, 2013).

B. The intelligence cycle

To obtain a good framework for wildlife health intelligence, one needs to follow intelligence cycles determined by existing intelligence organizations. The intelligence cycles found on the FBI and the Central Intelligence Agency (CIA) websites were used as a model. Different intelligence cycles can be found but the fundamentally process is the same (*Figure 3*). We have to first establish the requirements for the process.

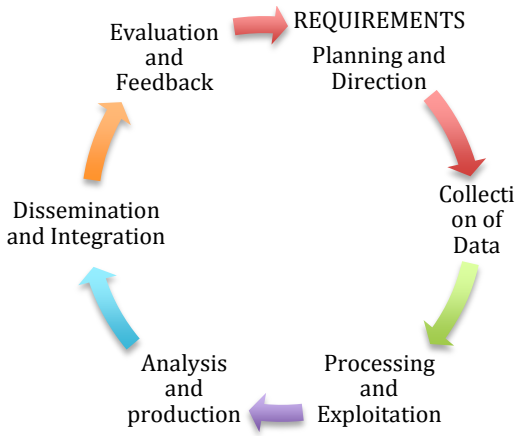

Figure 3: The intelligence cycle (modified from Anonymous, 2007)

C. Requirements for a wildlife health intelligence system

1. Possible indicators of wildlife health determinants and outcomes

The human population health approach served as a model to better understand the notion of health determinants and outcomes. This approach is based on how different factors and conditions interact to influence population health and uses resulting information for decision-making (Public Health Agency Canada, 2012). Public Health Agency Canada states that health is determined by complex interactions between social factors, the physical environment and individual behaviors. These factors are referred to as "determinants of health". (Public Health Agency Canada, 2011). What is produced in terms of changes in the health is called health outcomes (WHO, 2013). Parrish (2010) explained, "Positive health outcomes include being alive, functioning well mentally, physically, and socially, and having a sense of well-being. Negative outcomes include death, loss of function, and lack of well-being. In contrast to these health outcomes, diseases and injuries are intermediate factors that influence the likelihood of achieving a state of health."

The concept of tracking both determinants of health and multiple health outcomes within the context of expectations, needs and resources is not new to veterinary

medicine. It is the foundation of modern herd health (Risko and Retamal, 2011) where health-monitoring programs parallel health intelligence systems. In addition to death and disease, multiple outcomes are traditionally measured integrated in herd health assessment including reproduction and multiple measures of productivity. Health determinants are always taken into account to solve either specific health issues like milk somatic count problems or to enhance herd health management plans (Barkema *et al.*, 2013 ; Whittier and Currin, 2009).

Wildlife health determinants will be separated into those related to bio-physical factors and the social environment that affects wildlife determinants of health. For example the daily living environment of animals, which provides foundational determinants of health such as food and water, is necessary affected by human proximity and presence. Human wildlife management or landscape management will influence animal ability of cope with changes. It is the combined influence of the determinants of health that determines health outcomes like death, disease, longevity or reproduction.

Other organizations are advocating tracking both animal health outcomes and determinants, including a consideration of social drivers of animal health. The Global Early Warning System for Animal Diseases including major Zoonoses (GLEWS) and the Food and Agriculture Organization (FAO) have mentioned the importance of new data watching. The GLEWS explains : "Wildlife incidents are reported occasionally and without complete epidemiological information. More complete data that includes specific species affected, number of dead and sick animals, a precise geo-location, and any pertinent epidemiological and environmental information such as habitat, proximity to domestic farms, etc. would make the information more complete and provide necessary information that enables appropriate disease outbreak investigations and disease prevention and mitigation strategies […] FAO is encouraging the use of an unofficial wildlife morbidity and mortality events reporting system the Wildlife Health Event Reporter (WHER) which is linked to the FAO EMPRES-i system to increase global early warning capacities using wildlife disease surveillance information." (GLEWS, 2013). Socio-economics drivers are considered as incentives for high-risk behaviour that lead to environmental change and that produce high-risk interactions (FAO, 2011). Indeed, "It is essential to monitor and analyze trends and issues that affect agriculture and animal health, particularly societal, technological and industrial changes to help determine when and where conditions are optimal for disease emergence. It is important to generate new hypotheses for disease emergence and factors associated with disease emergence as it is to monitor already familiar risks" (FAO, 2011).

In order to translate the theoretical idea of health intelligence into a measureable program of activity, specific indicators are needed. An indicator is "a measure of interest which is used to indicate some concept, construct or process that we cannot measure directly" (Flowers, 2005).

There are two types of health indicators.

- Health status indicators measure health outcomes and/or risk factors. Examples of wildlife can include disease, death, injury, or fecundity, or fitness. Risk factors could include changes in social and environmental determinants of health such as changes in available habitat or hunting regulations.

- Performance indicators measure aspects of the health intelligence system performance and are tools for the performance monitoring. These aspects can be related to the functioning (utilization, accessibility), management (cost, communication) or infrastructures (Pope, 2003).

Table 3 provides a summary of the concepts found in the scoping literature review described above and nominates some candidate indicators that could be part of a wildlife health intelligence program. Cait Nelson mentioned "observation", and "passive and active surveillance" can have different meanings even within BC. A definition matching the meaning used by the BC Wildlife Management Branch was elaborated with her help.

HEALTH FACTORS	**PRINCIPLE**	**Species specific METRICS**			
		Subject	**Characteristics**		**Data Examples**
HEALTH DETERMINANTS					
Physical and Social Environment	HABITAT	Type	Spatial features		Dimensions captures all of specific habitat types
		Climate	Weather data		Temperature, Humidity and Rainfall variability
		Air	Air quality		Air pollutant index, Visibility, particles, Rain acidity
		Soil	Geomorphology		Glaciers, Coastal changes (erosion)
			Geologic processes		Seismic Activity, Cave air quality
			Soil Quality		Soil Analysis, Structure, Stability, Permafrost, Fertility
		Water	Water Body type		Ocean, Sea, River, Lake, Lagoon (brackish water), Reservoir
			Availability	Quality	Water analysis (minerals, chemicals, microorganisms), Pollution source (sewers, chemicals), Eutrophication, Acidity
				Quantity	Number of water bodies, Dimensions
			Accessibility		Location, Water access
		Food	Food type		Vegetation, Fruits, Prey
			Availability	Quality	Nutritional analysis, Pollution exposure, Diversity
				Quantity	Dimensions of vegetation spread, Abundance of the prey
				Suitability	Invasive Alien Species presence and depredation
			Accessibility		Location, Food access
		Shelter	Shelter type		Vegetation, Cave, Burrow
			Availability	Quality	Vegetation density, Dimensions, Ground type
				Quantity	Surface of vegetation density higher than *x*
			Accessibility		Location, Access
		Indicator Species			Status : Endangered vs Abundant
		Use	Distribution		Location of individuals or herds

HEALTH FACTORS	PRINCIPLE	Species specific METRICS		
		Subject	**Characteristics**	**Data Examples**
				and their predators
		Human proximity	Villages/Cities/Houses/ Campgrounds	Distance, Location, Dimensions
			Infrastructures (Trails, Roads, Buildings)	Distance, Density, Location, Dimensions, Layout
		Human presence	Villages/Cities/People settlements	Distance, Number of inhabitants
			Land use practice	Agriculture type, Forestry, Tourism
			Habitat fragmentation	Total available habitat dimensions, Fragments dimensions, Distance between fragments, Average size of fragments, Standard deviation of size's fragments
			Infrastructures (Trails, Roads, Buildings) Frequentation	Number of persons or vehicles per day, month or year
			Noise/Light Pollution	Hours per day, species affected
			Wildlife/Human Interactions	Species, Type of interaction, Number of interactions per day, month or year
Social Environment	WILDLIFE MANAGEMENT	Government policies and laws		Goals, Objectives, Actions, Results, Evaluations and Feedback
		Non government organization strategy management		
		Health conflict with human and domestic animals		Wildlife-related injuries, Zoonosis, Wildlife-related diseases
		Depredation[1]		Agriculture, Infrastructures and Neighbourhood damages
HEALTH OUTCOMES				
Death		Carcass observations[2] Sampling (passive[3] and active[4] surveillance)		Species, Date, Location, Cause of death, Age, Number of dead, Other species
Longevity		Age distribution		Number of adult, Number of juveniles
Abnormal Behaviour		Behaviour Observations[2] Sampling (passive[3] and active[4] surveillance)		Species, Clinical signs, Date, Location, Cause, Age, Number of cases, Others species
Disease				
Stress		Behaviour		Laying, Standing, Running, Walking
		Stress level		Stress Hormones (Feces, Hair, Blood)

HEALTH FACTORS	PRINCIPLE	Species specific METRICS		
		Subject	**Characteristics**	**Data Examples**
Productivity		Reproduction	Age distribution	Number of adult, Number of offspring
		Abundance		Number of individuals
		Genetic diversity	Sampling (Feces, Hair, Blood)	Genetics
		Resources	Human use of Wildlife	Hunting, Poaching records Numbers of individuals used for cultural or work use
Disability		Mobility	Behaviour Injuries	Standing, Running, Walking
		Activity		Hunting, Feeding, Watering, Reproducing
Nutritional Status		Body condition		Rump fat and Rib fat measurement

[1] *Depredation :* synonym of destruction, ravaging, devastation (Collins dictionary)
[2] *Observation :* The action of observing carcasses, signs of disease or abnormal behaviour and reporting the observation to some responsible agency
[3] *Passive surveillance :* This means opportunistic sampling on dead animal
[4] *Active surveillance :* This means to go out and collect samples for a particular disease

Table 3: Health Factors and data to collect within the context of wildlife intelligence

There are a lot of different ways to collect data needed to complete *table 3* ; it can involve individuals, organization, groups, and/or internet-based research. As interviewing the herder in the case of dairy cattle farming is a crucial point to assess the herd health, workers and citizens can collect primary wildlife information on the health factors introduced in *table 3*. Population participation allows a passive and widespread watching all year long and must not be put aside. Several examples prove that indigenous participation is an important ecological management factor and when local population is not involved in the project, some purposes cannot be reached (McNeely *et al.*, 1990 ; Ransom *et al.*, 2012). Rinderpest is a good example requiring population involvement. Eradicated in 2011, the surveillance of the disease is still ongoing. "A relevant realization was that community often had better intelligence on the geographic distribution of Rinderpest risk and the history of disease in their area than national veterinary services, and could provide information that, when analyzed from a risk-based perspective, led to active outbreaks of Rinderpest being detected" (FAO, 2011). Many of the sources of data required to complete *table 3* would not be found within animal health programs. Partnerships with other government agencies, non-governmental agencies and the private sector would most likely be required. Health intelligence therefore could require a collaborative and participatory approach.

2. Features of good indicators for Health Intelligence

Table 3 proposes indicators and criteria for wildlife health intelligence built from pre-existing approaches to herd health and human population health. There are many practical issues that could restrict access or use of some of the proposed data. However, before confronting those challenges, it is important to first consider how to

maximize the quality of the data that could be incorporated into a health intelligence system. An important next step to developing the final health intelligence model is, therefore, criteria for identifying "good" indicators.

Numerous different indicators exist but little research has been done to determine the features for a good indicator. However, some features of "good" health indicator have been proposed (Pope, 2003 ; Flowers *et al.*, 2005 ; Bird *et al.*, 2005) (*Table 4*). Future development of a wildlife health intelligence system should apply *table 4* or similar criteria to possible data sources being considered for inclusion in the system.

Information to precise	Features for a good indicator
Title	Declarative and descriptive
Origin	The organization or unit from which the indicator is originated or the origins of the data used for the indicator calculation
Target	The broad policy area allocated to the indicator
Relevance	An indicator has to be an obviously proxy for the underlying measure. In case of performance monitoring, it should be relevant for the monitoring objective previously defined.
Association	Indicate if the indicator is associated with a structure, process or an outcome
Goal	The purpose of the indicator : communication, sampling data
Face validity	Try to use existent indicator if possible
Construct validity	The indicator has to be valid in that it is likely to measure what it is supposed to. And the construction of the indicator has to be simple and make sense : specify the numerator and denominator if needed and the comparator
Collection mode	Routine or special collection
Unit	Unit of the analysis : place, institution, person…
Frequency	An indicator has to be monitored with appropriate frequency to support change watching.
Method	Quantitative or Qualitative
Calculation if necessary	Indicate the operation : simple division…
Behaviour	An indicator should have the statistical potential to reveal change in the underlying elements and its modification should be interpretable.
Repeatability	An indicator and its definition have to be consistent over time. Changes in data collection for example have to be watched. A significant change could lead to revise the indicator.
Influence	Specify in that the indicator can influence or improve a practice or behaviour.
Strengths	Indicate the strengths of the indicator
Weaknesses	Indicate the weaknesses of the indicator
Risk of gaming and perverse incentives	An indicator must avoid creating perverse behaviour because they could lead to bias.
Balance	An indicator should be balanced and no focus on a precise part of the system.

Table 4: Features for a good indicator

D. Key informant interview results

Participants to the questionnaire

Seven out of 20 key informants invited to participate answered the questionnaire ; achieving our target of 6 respondents for potential data saturation. The experts' job responsibilities dealt with wildlife and domestic animal health, and disease management or wildlife research. They represented a variety of jobs including private veterinary practice, Ministry of Forests, Lands and Natural Resource Operations, Ministry of Environment, NGOs, zoological parks or wildlife rehabilitation centres. Some of the participants held several positions at the same time.

Awareness about ongoing wildlife-related projects

The participants were all well aware of wildlife management, conservation or disease management programs in BC. The question was left opened on purpose and the answers overstepped my expectations. They gave between 2 and 10 programs' names. About 20 different programs were cited as example targeting different species of birds, bats, frogs, turtles, caribous and marmots.

Awareness about wildlife health intelligence

Only one participant was aware about the wildlife health intelligence existence. He wrote "I have worked with CCH and CFIA (Canadian Food Inspection Agency) on this notion and CCWHC has pioneered some approaches to measuring parameters relevant to wildlife health (versus disease)".

Wildlife health intelligence purpose

The participants shared the same vision of the purpose of wildlife health intelligence. It is a means to support wildlife health protection and wildlife species conservation. Protection of wildlife from diseases appeared to be the second most important goal whereas criteria involving humans, human protection from zoonotic diseases and humans and domestic animals protection against animal conflicts, were ranked respectively as 3rd and 4th place.

Required data

After reviewing *Table 3*, keys informants concluded that the data we proposed to collect made sense.

Some participants made remarks about the completeness of the table.

Abundance of a species - Critical mass, as the minimum number of individuals pooling enough genetic diversity to ensure the species sustainability, has been mentioned to be important to take into account when assessing the abundance of a species.

Social environment - Stress was also put on social environment. "Social environment would include zoning laws that define what activities can be done on a piece of land. Zoning is more often used at the municipal level of government, but the same principle applied to designating land as protected, as national or provincial park, etc. and each designation includes regulations about permitted human activities."

Physical environment – Unexpected events like storms and fires have to be consigned because they affect the environment.

Behavior and disability – Distance travelled per unit of time should serve as an index to assess the normality or disability of a behavior.

Nutrition – The experts' opinion differed on what is the best way to assess the nutritional status of an animal. On one hand, some assumed various body condition indices have been developed for different groups of animals and so these are better measures of body condition than just fat reserves. However, there are challenges to measuring body condition in a standardized manner. For example, Northern caribou body condition was assessed on live capture of free ranging animals for a translocation project within BC. The assessment was done visually on animals anesthetized after capture by several biologists with experience handling caribou but without using a standard protocol. There is no standard method of assessing caribou body condition so they were assessed as poor, moderate or good body condition. After transport and prior to release each animal was again anesthetized and re-examined but this time an ultrasound was performed to assess rump fat in a method previously used on other caribou and by an experienced team. A lack of agreement between the two methods for assessing body condition was revealed (Dr. Helen Schwantje, personal communication).

Data collection actors in BC

Determining who or what agency might have data, now or in the future, or might help with data collection for each of the categories of health data listed in *Table 3* was the most challenging part of the questionnaire. Five out 7 participants answered the table. Potentials actors proposed (wildlife agency veterinarian, private practice veterinarians, provincial or federal park employees, independent biologists and researchers, Canadian Food Inspection Agency staff, specific group of volunteers, the general public, First Nations members, trappers, hunters, anglers, tourists and wildlife viewers (recreationalists), geocachers and cavers, heli-skiing and heli-hiking companies, guide outfitting industry, back country horseback riders, road maintenance crews, bird watchers, wildlife rehabilitation community , naturalist community, farmers and ranchers, game farmers, conservation groups, NGOs, others) were all approved by the informants. Moreover, a list of Ministries that might be useful in the data collection was submitted. The Ministry of International Trade of BC was the only one to be judged unlikely to have relevant information within that list. In BC, the Ministry of Aboriginal Relations and Reconciliation, the Ministry of Agriculture, the Ministry of Community, Sport and Cultural Development, the Ministry of Energy and Mines, the Ministry of Environment, the Ministry of Forests, Lands and Natural Resource Operations, the Ministry of Health, the Ministry of Jobs, Tourism and Skills Training, the Ministry of Natural Gas Development and the Ministry of Transportation and Infrastructure were considered as source of data with already existing data base. *Appendix 3* presents the results. The NGO Ducks Unlimited, involved in the conservation of wetlands and associated upland habitats for waterfowl and other wildlife, was also cited a source of data by one of the participant. Experts specified that sometimes they had to assume the existence of a few database. I did not have enough time to check with the different Ministries the reality of these suppositions but the *appendix 3* can constitute a foundation for further investigations. Some databases already exist in various ministries and a lot of different actors could be involved in the data collection. In conclusion, there would be a broad range of sectors able to provide data relevant to our theoretical frameworks for a wildlife health intelligence system.

Top 5 reliable data to collect and limitations

We asked informants to nominate their top 5 pieces of information that were believed to be the most reliable, feasible to collect and consistently collectable (repeatable). The informants did not provide the same 5 sources. *Table 5* is an attempt to gather the informant's nominees into key themes.

Topics / **Data**	**Physical and social environment : habitat**	**Social environment**	**Health outcome**
Data considered the most reliable, feasible to collect and consistently collectable	Spatial features Weather data Water body type Habitat location	Wildlife Management – Government policies	Death Stress Age distribution Genetic diversity
Examples of specific sources, proposed by the informants, that could help	*Vegetation Resource Inventory (VRI)* *Integrated Land Management Bureau (ILMB) / Government Spatial Data* *Species Inventory Database (SPI BC MOE)*	*Wildlife Act*	*BC Wildlife Health Database* *Animal Health Centre*

Table 5 : Data considered the most reliable to collect for the implementation of wildlife health intelligence

The primary limitations to collecting other data in a reliable and repeatable manner were said to be the lack of knowledge about where the data could be found and funding limits. The time to collect the data, the difficulty of the data collection and the lack of training about proper techniques to assess health in individuals or population, even among trained veterinarians were also mentioned. Finally, informants declared most other data are not measured consistently enough outside of human settlements and are more likely to be qualitative rather than quantitative measures.

Three essentials

Table 3 is an extensive list of possible indicators that provides more options for data sources than is likely feasible for a single program to manage. We asked the informants to identify the three essentials data that would allow us to quickly and reliably evaluate wildlife health independently from collection reliability.

Habitat quality - Experts agreed that habitat is an important component to take into account. Habitat quality was a recurrent answer. One justification was "without habitat you have no healthy populations". It was strongly linked with nutrition quality and habitat use by the informants and they identified body condition spatial features and human presence as indicators of habitat quality. One participant mentioned health conflicts with humans and domestic animals, which is directly related to habitat use. He explained, "As humans encroach on critical habitat there will be increasing conflict with wildlife […] A wild animal that dies from a CO's (Conservation Officer) bullet is no different than one that dies from injury or disease."

Death/Disease/Abnormal behavior – Death, diseases and abnormal behavior were usually associated together. They are the most likely events to be observed and reported and these data are already collected for disease surveillance in BC. However, stress was stated to be interesting too because methods exist to quantify non-acute stress and would permit a comparison across years to assess trends.

Productivity – Key informants considered the population growth rate and the age distribution as an important quantitative indicator of wildlife population health.

Wildlife species of first priority in BC

Experts agreed about priority species but not necessarily about their relative importance. We organized proposed species by clades, number of citations by participants and given ranks (*Table 6*). Frogs and bats were the two species most often mentioned. They are threatened, respectively by, the chytrid fungus *Batrachochytrium dendrobatidis* (Bd) and White Nose Symdrome that cause drastic decline of populations (CCWHC, 2013a ; CCWHC, 2013b). One participant assumed Chytrid fungus is expected to eliminate all frogs in BC within a decade. White Nose Syndrome was one of the topic of the 2013 CCWCH annual meeting in Saskatoon and was revealed to be spreading beyond the East coast of Canada.

Clade	**Species**	**Cited by *x* participants out of 7**	**Given ranks from 1 to 5 (number of times)**	**Reasons for being ranked as important by interviewees**
AMPHIBIANS AND REPTILES	All in general	6	2(2), 4(4)	At risk globally and in BC, No protection and the chytrid fungus *Batrachochytrium dendrobatidis* (Bd) may eliminate all frogs within a decade
MAMMALS	Bats	4	1(2), 3(2)	Threat of White Nose Syndrome in BC, No data, Becoming at risk in other locations
	Moose	3	1, 2(2)	Declining in some areas : salvage logging of beetle-killed pine forests and over hunting are possible causes, No data, Hunting importance : social interest and existing access to sample
	Woodland caribou	3	1(2), 4	At Risk, No Data, Declining
	Bighorn sheep	3	3, 5(2)	Threat of domestic sheep disease transmission and pneumonia outbreaks, High hunting, Wildlife viewing value
	Badger	2	3(2)	Declining, at Risk
	Mule/Black-tailed deer	1	2	Key terrestrial species susceptible to emerging diseases like Chronic Waste Disease and Adenovirus
	Cougar	1	2	Seriously over rated as a threat to humans and domestic animals and are far too quickly eliminated (shot) out of convenience
	Grizzly/ Brown bear	1	5	Keystone (top consumer) species sensitive to all disturbances
	Sea mammals	1	5	Presence of toxins
BIRDS	Song birds	1	1	In noticeable decline
	Corvids	1	2	West Nile Disease surveillance
	Trumpeter swans	1	3	Lead poisoning
FISHES	Wild salmon	1	1	Key species in several ecosystems
	Pacific herring	1	3	Key species in marine ecosystem

UNDEFINED	Alien Invasive Species	1	5	Species such as the Eastern Grey Squirrel, Starlings etc, are, essentially, diseases in and of themselves in our habitats.

Table 6 : Proposed first species that should benefit from a wildlife health intelligence in British Columbia (BC)

Data analysis and application

All participants were not familiar with data application. However, they agreed on the necessity of a high quality and timely data ; features that would determine the type of data processing that could be done. The data analysis methods proposed were meetings, mapping, graphing, statistics and modeling (*Table 7*). BC was judged to have the necessary skills and resources to apply these methods. Nobody proposed additional data analysis methods.

Data processing examples	Product examples	Needed Skills	Infrastructures or Material Needs
Meeting	Exchange of human intelligence and experience	Data knowledge Communication	Meeting place
Mapping	Maps of species habitat, distribution, abundance, wildlife and human interactions	Geographic Information System Drawing	Informatics devices Paper
Graphing	Health outcomes and Habitat Evolution	Informatics skills: i.e. Excel Mathematics skills	Informatics devices Paper
Statistics	Indicator change detection	Statistics skills, Informatics skills	Informatics devices
Modeling	Predictive models of future changes	Statistics skills, Informatics skills	Informatics devices

Table 7 : Data processing capacities as identified by key informant interviews

Gaps and Needs

Informants identified the gaps for the implementation of a wildlife health intelligence program in BC and the short and long term actions that can be done to make this program feasible.

Coordination, capacity and funding - The most outstanding gap seen by the interviewees was the lack of coordination of the collection of data. Existing capacity and funding were seen as real limiting factors.

Short term actions - Informants mentioned several short term actions. To close the gaps they identified within one or two years, they suggested a coordinated effort to find out just what data is desired, and a comprehensive strategy on how to best collect it will be needed. Data collection that is done in the United States was proposed as a potential model. And then one must make it worthwhile for

stakeholders to assist in the collection i.e. inducements. Informants agreed a wildlife health intelligence program should start out in one or a small number of ecosystems/geographic areas, should have specific objectives. And it could also focus at first on a typical audience : First Nations or the hunting community have been mentioned. In my opinion, actually, these communities are likely to be the most concerned about wildlife health as they rely on wildlife for every day living or leisure. Informants mentioned that trying to achieve these suggestions will drive the evolution of the program and guide development or selection of the data choices, data gathering methods, analytical objectives and methods and use of intelligence to inform social decisions.

Securing government commitment to funding such a program and acting on the results was stated as a short-term objective as well. But one participant answered "Habitat protection is the lynch pin or cornerstone for wildlife health. Without adequate habitat protection (and enhancement) and a healthy, genetically robust critical mass of all wild species within in each biogeoclimatic zone, and the complete protection of a significant number of each of these zones throughout the province from unfettered development, the micro-details of a health intelligence program will be of little value." It appears habitat protection should be an essential parallel enhancement project.

Long term needs actions - Within five to ten years, key informants specified a progressive program of expanding the geographic and ecological coverage of the province and the establishment of methods to gather data for the most useful parameters and the analytical approaches that provide the most useful decision support should be implemented. Moreover, knowledge mobilization and advocacy were mentioned to be needed to help the Ministry of Environment of BC improve its understanding of the critical importance of protecting wildlife and who acts to protect the environment.

E. General gaps

We found no paper about the gaps of wildlife health intelligence. Wildlife health intelligence is a new concept, so, assessing the gaps of such a system is quite a challenging task, but the questionnaire participants have anticipated some of them. We tried to approximate possible gaps by reviewing challenges to known component of the health intelligence system ; animal and zoonotic surveillance. An international workshop lead by the FAO on the Challenges of National, Regional and Global Information Systems and Surveillance for Major Animal Diseases and Zoonoses in November 2010 involved experts from around the world. The thirty-four participants were from a broad-range of international and regional organizations, national veterinary, medical and other health-related services, academic institutions and non-profit organizations. The workshop considered high-income countries, LMICs, and international organizations. These experts produced a list of 27 criteria (*Table 8*) that limit effective regional and international surveillance for animal and zoonotic diseases (modified from FAO, 2011).

Number	General limiting factor for animal and zoonotic disease surveillance
1	Uneven quality of national surveillance

2	Lack of data standards for reporting
3	Lack of effective surveillance of wildlife diseases
4	Insufficient coordination between international bodies
5	Lack of data sharing between international organizations
6	Use of proprietary (non open-source) software for data storage and analysis
7	Lack of effective laboratory capability in many countries
8	Insufficient training in surveillance methodologies
9	Insufficient funding for surveillance
10	Reluctance of many national governments to share data (aside from obligatory reporting)
11	Lack of leadership by international and regional bodies for surveillance
12	Lack of tools to electronically capture field data
13	Insufficient feedback to data collectors and/or data providers
14	Difficulties in linking and integrating laboratory data from public and animal health agencies
15	Difficulties in linking and integrating data from public and animal health agencies
16	Weakness of national laboratory networking
17	Difficulty in capturing data from private laboratories
18	Difficulty in engaging expertise from other organizations for data exchange methods
19	Failure of sustainability of surveillance implementation in developing countries due to dependence on project funding
20	Authorities too focused on their individual mandates, instead of thinking collaterally to communicate, cooperate and collaborate
21	Problems of data coordination in decentralized national administrations
22	Lack of appropriate strategies for economically important diseases
23	Lack of sharing experiences of successes and failures of disease control programs, including surveillance
24	Lack of epidemiological capacity (including human resources, tools etc.) at the national and sub national levels
25	Lack of understanding of national and sub national decision-makers and of stakeholders on the importance of surveillance
26	Lack of coordination between neighboring countries on surveillance activities
27	Lack of defined vocabulary for surveillance to facilitate data exchange

Table 8 : Factors limiting effective and international surveillance for animal and zoonotic diseases (modified from FAO, 2011)

Tracking health outcomes and health determinants information is based on the same general techniques that is to say collection, sampling and analysis (*Table 2*). The limiting factors discovered through our key informant interviews are similar to those found in the table above derived from the FAO meeting. This suggests that the obstacles for general animal surveillance will be need to be considered when developing wildlife health intelligence systems.

In addition to the list above, timeliness of reporting is a key limiting factor. Reviewing syndromic surveillance in LMICs, May *et al.* (2009) settled that to improve timeliness of reporting, the efforts should be focus on enhancement of communication infrastructure including the internet access, increasing use of automated reporting and the use of volunteers in low staffing areas.

Because intelligence improves with a longer term understanding of trends, I have to add a lack of long-term planning as a possible limiting factor for a health intelligence system. Identifying general trends in changing interactions between every targets of the system (environment, humans, domestics animals and wildlife) to assess future needs requires anticipation via statistics and modeling based on historical data (FAO, 2011).

F. Low and middle income countries specific needs

The need to build capacity in wildlife health in LMICs to empower countries to meet their own needs autonomously has been recognized elsewhere (Leighton, F.A., 2011).

Poor reporting enhancement

Poor reporting is one of the main issues in developing countries' diseases surveillance system. Several obstacles have been identified and will have to be overcome : (i) a lack of noticeable benefits when reporting such as feedback and beneficial responses to mitigate disease problems ; (ii) a lack of capacity to enforce regulations ; (iii) poor communication between institutions at national level and (iv) disincentives that can exist for international reporting system (Halliday *et al.*, 2012).

Leadership and communication

The first and essential requirement for a working system is to have an efficient leadership. National and international partners have to work in a mutually effort. It would often result in a multiple of parallel disease specific surveillance system using separate resources (Saint Louis M., 2012). Data integration can combine these multiple surveillance systems as a source of information for a health program but it is efficient only if the government considers the latter as one of its responsibility (Saint Louis M., 2012). Communication is an important point to develop to keep active international cooperation and effective system (GAO, 2001 ; FAO, 2011).

The FAO workshop (FAO, 2011) also produced a comparison of limiting factors of disease surveillance that show they are clearly influenced by the income level and the scale (*Table 9*).

Top 5 limiting factors by group
HIGHER INCOME COUNTRIES
1 - Authorities too focused on their individual mandates, instead of thinking collaterally to communicate, cooperate and collaborate
2 - Lack of understanding by national and subnational decision-makers and stakeholders of the importance of surveillance
3 - Lack of defined vocabulary for surveillance to facilitate data exchange
4 - Difficulties in linking and integrating data from public and animal health agencies

5 - Failure of sustainability of surveillance implementation in developing countries due to dependence on project funding
MIDDLE INCOME COUNTRIES
1 - Lack of understanding of national and subnational decision-makers and stakeholders of the importance of surveillance
2 - Insufficient funding for surveillance
3 - Lack of coordination between neighboring countries on surveillance activities
4 - Lack of data standards for reporting
5 - Lack of leadership by international and regional bodies on surveillance
LOWER INCOME COUNTRIES
1 - Insufficient funding for surveillance
2 - Lack of epidemiological capacity (including human resources, tools etc.) at the national and subnational levels
3 - Insufficient training in surveillance methodologies
4 - Lack of understanding by national and subnational decision-makers and stakeholders of the importance of surveillance
5 - Lack of effective laboratory capability in many countries
INTERNATIONAL/REGIONAL ORGANIZATIONS
1 - Insufficient training in surveillance methodologies
2 - Authorities too focused on their individual mandates, instead of thinking collaterally to communicate, cooperate and collaborate
3 - Lack of epidemiological capacity (including human resources, tools, etc.) at the national and subnational levels
4 - Difficulties in linking and integrating data from public and animal health agencies
5 - Lack of understanding of national and subnational decision-makers and stakeholders of the importance of surveillance

Table 9 : Top 5 limiting factors by group in conducting effective regional and international surveillance for animal (domestic and wildlife) and zoonotic diseases in order of importance (modified from FAO, 2011)

Funding, transportation, capacity, training, coordination and understanding

It appeared that LMICs main limiting factors are related to the lack of funding and transportation, epidemiological capacity, specific training, coordination and understanding of decision-makers (GAO, 2001).

G. Sri Lanka needs

Context

Sri Lanka is classified as a lower middle income country (The World Factbook). Three different colonial times and a 25-years-long civil war opposing the two main ethnic group, the Tamil and the Sinhalese people (*Appendix 4*), which ended in 2008 left their mark on the national culture and government organization. The latter is quite complex with three different scales ; national, provincial and community level (*Appendices 5 and 6*). Sri Lanka has several official languages and English is not understood and spoken by an important part of the population. Wildlife is important in Sri Lanka in the manner it affects the every-day life. It could be in a positive way ; the Buddhist population revere elephants as sacred, or on a negative way like human-elephant conflict resulting from destruction of agricultural fields (BBC, 2011). The most common diseases that occur in wildlife and impact on human, livestock and trade are rabies, bovine tuberculosis, Newcastle disease, brucellosis, foot and mouth

disease, fowl cholera, leptospirosis and haemorrhagic septicaemia, but their prevalence are not known. This threatens the health safety and economy as tourism, and eco-tourism in particular, are on of the most important income source for the country (Valeix *et al.*, 2011).

Valeix *et al.* (2011) produced the foundation of this project and concluded that enhancements in central coordination, education, transportation of people and samples, specialist training and diagnostic facilities were needed in order for Sri Lanka to develop a wildlife health program in general.

Leadership and communication

The administrative organization of veterinary services split into the different scales as well. As explained by Sawford *et al.* (2011), under the Livestock and Rural Community Development Ministry, the DAPH, is in charge of disease surveillance for the World Organization for Animal Health (OIE). Under the DAPH, the only national-level government organization in Sri Lanka is the Veterinary Research Institute in charge of laboratory services with a wide range of laboratory diagnostic tests (*Appendix 7*). At the district level, the Veterinary Investigations Centers (VCI) are in charge of laboratory diagnostic too but in a restricted manner (*Appendix 7*). A Veterinary Investigation Officer (VIO) who is often an experienced Field Veterinary Surgeon (FVS) runs each one. They are located in Anuradhapura, Badulla, Hambanthota, Chillaw, Jaffna, Matara, Peradeniya, Rannala, Polonnaruwa, Ratnapura, Vaunia, Welisara, Kegalla, Nuwara Eliya, and Dambulla. Field Wildlife Veterinarians (FWV) are hired by the Wildlife Resources Conservation Ministry and the Department of Wildlife Conservation (DWC). The DAPH and the DWC are part of the SLWHC leadership team that manages SLWHC coordination. The DAPH and the DWC have begun a real collaboration. They accepted to share resources such as samples taken during intervention in wildlife being integrated into the DAPH samples chain. Moreover, the DAPH has created incentives for FWV giving them the opportunity to migrate into the DAPH system in order to promote (Dr. Craig Stephen, personal communication).

Education and Awareness

Interviewing a PhD student, Dr. Asha Perera, a Sri Lankan veterinarian training in Canada, she agreed population is not really aware of the importance of wildlife and need to be educated. She suggested children education would need to be a parallel process to developing government and scientific capacity and awareness. FVS also stressed the importance of education.

> "Participants expressed the belief that the best way to engage farmers in surveillance was through education. Prevention and treatment of more common diseases, contagious diseases and how to protect animals, signs of disease for which to monitor, the need to report clinical signs, and animal management were suggested as topics relevant to farmers." (Sawford *et al.*, 2011)

Transportation

Interviews of Dr. Craig Stephen, Dr. Ted Leighton and Jennifer Dawson-Coates, two veterinarians and one biologist working with Sri Lanka for over 7 years, confirmed the transportation issues. Driving 120 kilometers can take until 6 hours to

link two main cities and the annual average temperature is around 28°C. The DAPH's and DWC's health management programs are limited by this factor (Valeix *et al.*, 2011) as delays in transportation and challenges in maintaining a cold chain can affect the quality of diagnostic samples. Road infrastructure improvement is on going, but right now cold-chain transportation for samples is rarely achievable. FVS, as well, explained that transportation is really poor, there is not enough government vehicles available, or they are available for a limited number of days in a month or for a given distance in a month and some of them said they would not know how to cope with the transportation-related issues to sent a sample to a laboratory (Sawford *et al.*, 2011). Transportation remains one of the major points to improve.

Specialist training and sample submission

Additional technical personnel and veterinarians are needed, and to attract applicants, the employment conditions will have to be made attractive (Valeix *et al.*, 2011). On 11 available positions for FWV, only 7 are currently held and they are spread across the country (Valeix *et al.*, 2011). This number is not sufficient and they are usually busy dealing with humans and elephants conflicts. In 2009, a usual year, 228 elephants and 50 people were killed in these encounters (Rodrigo, 2010). Asian elephants (*Elephas maximus maximus*) are the most emblematic wild animals in Sri Lanka as they play a major role in the socio-cultural and economic life of the country and their management is a challenge.

All persons who will be involved in the wildlife program and especially in detection of disease in wild animals, diagnosis and information management will require to have a further specific training in wildlife-related matters and to be more aware about the importance of sample submissions when the objective is to watch the health of a population (Valeix *et al.*, 2011). FVS reported they sent in average 1 sample per month to 1 sample per year to the laboratory. This poor rate of submission can be explained by low transportation means (see below) but is also considered as a lack of knowledge (Sawford *et al.*, 2011). In March 2013, The University of Peradeniya launched the project "Building Research Excellence in Wildlife and Human Health in Sri Lanka" supported by the International Development Research Centre (IDRC) to close this gap. The overall objective of the project is to create a new and sustainable critical mass of wildlife health scientists in Sri Lanka with the capacity and ability to link wildlife health with human health and socio-economic improvement, and who are networked effectively through an established wildlife health research centre in order to fill critical gaps in emerging disease preparedness and in co-management of conservation, agriculture and public health (Anonymous, 2013).

Diagnostics and autopsies facilities improvements

Modest improvements are needed in diagnostics and autopsies facilities with in particular specimen-handling facilities, personnel protective equipment and storage facilities. Access to electronic communication such as cellular or the Internet was also evocated to enhance the coordination (Valeix *et al.*, 2011).

Collaboration and data sharing

With the BC example, we showed that the first step for the implementation of a wildlife health intelligence system is a broad data collection from different fields and different ministries. Sri Lanka has currently 66 ministries that multiply the number

potential stakeholders and make more difficult the cooperation. Interviewing Dr. Ted Leighton and Dr. Sam Daniels (Veterinarian, Ministry of Estate Infrastructure & Livestock Development, Sri Lanka), we identified the following ministries as potentials future actors that would have to be involved in the data collection process : Defense and Urban Development, Irrigation and Water Resources Management, Health, Livestock and Rural Community Development, Water Supply and Drainage, Local Government and Provincial Councils, Industries and Commerce, Power and Energy, Environment and Renewable Energy, Fisheries and Aquatics Resources Development, Land and Land Development, Agriculture, Disaster Management, Wildlife Resources Conservation, resettlement and Economic Development. Working with 16 different ministries will not be easy and rapidly implementable. The data and information sharing is not common in Sri Lanka, and some partnership have to be build and enhance before hoping moving forward (Robertson, 2010). Even after 7 years of collaborative work with the CCH, we were not allowed to process our questionnaire with Sri Lankan key informants.

Developing timely report systems

Commercial wireless services use to support healthcare initiatives in developing countries is gaining recognition and is known as "mHealth" (Vital Wave Consulting, 2009). In 2009, Gow and Waidyanatha tested the effectiveness of mobile phones use in a real-time human biosurveillance program in Sri Lanka and India to cope with the one-month delay between case detection and case report due to paper-based reporting methods. It appeared that mobile phone offered an innovative and potentially effective means to create a real-time or nearly real time report system in developing countries if some barriers are shot down. Roberston *et al.* (2010) tested the Infectious Disease Surveillance and Analysis System (IDSAS), a mobile phone-based surveillance program for animal populations and lower-resources countries. This system aimed at obtaining animal health information from FVS in a timely manner to establish baseline trends in domestic animal patterns. The study focused on cattle, buffaloes and chickens. Episurveyor, a free open-source software package developed for gathering public heath data was used (www.datadyne.org). GPS data were asked to be associated with every record and allowed maps creation. The number of submission (11 surveys/month/FVS) was better than expected and weekly surveillance reports were delivered to stakeholders. Some of the obstacles encontered during the study, like the cost of the hardware and the need for a service administrator, have been mentioned to be easily solved nowadays due to the availability of less expensive communciation technology. At the end, the Sri Lankan government decided to integrate this program to its routine heath surveillance program, and a national server was created in order to become autonomous in the next few years. This was dedicated to domestic animals and could be extended to wildlife with the involvement of FWV.

IV. DISCUSSION - Recommendations for the Sri Lanka Wildlife Health Centre

The global health system is facing the challenge of emerging infectious diseases within wildlife, and lower resource settings play a central role. The "One Health" approach seems to be more important than ever ; environmental, animal and human health are linked together. A wildlife health intelligence system whose aim is to gather and timely report information to decisions makers in order to improve the health of the wildlife population and so, indirectly, the health of the human population at the same time, is needed. Like military intelligence, it will hopefully allow detection of changes in wildlife health determinants and outcomes in advance of harm. This study does not give a complete description of a whole intelligence system as presented in the intelligence cycle (*Figure 2*) but at least introduces the requirements, the data collection and proposes analysis methods necessary for wildlife health intelligence.

The foundation of a wildlife health system is a broad-range data collection from different actors who can be part of the government, NGOs, health professionals or simply citizens involved in activities exposing them to wildlife. The main features are an open and clear communication between all the persons implicated in the project with a strong collaboration and partnership between the intra-national structures.

In high-income settings (BC), the implementation of wildlife health intelligence appeared to be feasible. Federal and provincial institutions, health related professionals and citizen that are likely to be necessary for the data collection have been identified and some databases already exist. Interviewees identified coordination for the data collection, capacity of persons and funding as the challenges in BC.

In low-income settings, leadership, transportation, training, and understanding have been identified to be additional challenges (FAO, 2011, GAO, 2001).

Building capacity in health research is an important global concern in developing countries and even more within the context of global warming. Sonia Altizer, an associate professor in the University of Georgia's Odum School of Ecology, said "For a lot of human diseases, responses to climate change depend on the wealth of nations, healthcare infrastructure and the ability to take mitigating measures against disease" (National Science Foundation, 2013). The three generic principles to respect in capacity building are (i) a stepwise approach : we need to proceed in a certain manner to build solid foundations and involve stakeholders sequentially ; (ii) strengthening of existing capacity and (iii) creation of partnerships between the main local structures involved to share leadership, responsibilities and obligations and make them the owner of the new capacity and integrate the latter within the country (Bates *et al.*, 2005).

Bates *et al.*'s review (2005) and interviews with Dr. Craig Stephen, who has had multiple experiences in capacity building, highlighted the successive stages necessary to capacity building : (i) awareness during which local decision makers identify needs, goals and objectives of the new project ; (ii) implementation during which the context is built by partnership creation and first objectives are achieved : (iii) expansion during which the totality of the program objectives have to be met, and (iv) consolidation during which the new capacity is fully integrated into daily responsibilities of local structures.

Sri Lanka is not ready yet for the implementation of a wildlife health intelligence system. Based on the review of literature and key informant interviews, I have concluded that the challenges Sri Lanka has to cope with for development of a wildlife health intelligence system are ; leadership and communication, education and awareness, transportation, specialist training and sample submission, diagnostic and autopsy facilities improvements, collaboration and data sharing and developing a timely report system. However, Sri Lanka is located within the area at highest risk for the emergence of EIDs (Woolhouse and Gowtage-Sequeria, 2005) and wildlife is a big concern and a crucial value in the everyday socio-economical and cultural life (Valeix *et al.*, 2011). In order to protect both humans and animals, wildlife health intelligence is needed. However, the SLWHC is still in its early stage of building awareness and implementing a research program. The latter have to be completed to allow the project to move forward. The creation of the SLWHC is proof that Sri Lankan stakeholders have recognized the importance of building capacity in wildlife-related research. Interviews realized during the feasibility study for the implementation of the SLWHC identified education, training and modest infrastructures as a fist step in development (Valeix *et al.*, 2011). The launch of the project "Building Research Excellence in Wildlife and Human Health in Sri Lanka" and the creation of partnership between the FVMAS, the DAPH, the DCW and, recently, the Ministry of Health show that some primary objectives are on their way to being met. However, enhancements are still needed to strengthen the foundation of the SLWHC. I believe the first targets the SLWHC has to focus on should be the ones essential to achieve the awareness of national institutions and citizens, and those necessary for the implementation of the first step of the project, that is to say the data collection : education of health professionals and population, communication, and partnership and collaboration creation between the different structures previously identified thanks to the help of Dr. Ted Leighton and Dr. Sam Daniels.

Awareness

Ministries and national institutions – Awareness of these actors has to be continued as they are essential for the data collection and it is a required step before collaboration building.

Population - As we mentioned, the involvement of the population is one of the main factors determining the success of a program. Engaging community is essential for three reasons : (i) nowadays, citizens expect to be engaged more than ever in decisions that affect them ; (ii) citizens are more likely to accept the work of governmental and official agencies if community engagement has been part of the overall official decision-making process, and (iii) community engagement can reveal strengths in the community that can help government and official agencies solve societal problems (Butler *et al.*, 2006). Population's awareness of the importance of wildlife and the environment should be raised as soon as possible and citizens should know about the existence of the SLWHC and its role. The expected benefits of the program should be exposed to serve as incentives. A healthy wildlife population will prevent humans from being affected by zoonoses and will preserve the tourism-related economy and a safe cultural life. Moreover, human-elephant conflicts could hopefully be managed in a long-term manner if location of wild population is monitored and zone at risk identified.

Partnership and collaboration

International and intra-national collaborations have to be strengthened. International institutions provide part of the funding for the SLWHC and leadership is co-managed by different national ministries and institutions. New partnerships should be created between the SLWHC and the ministries identified as potential actors by Dr. Ted Leighton and Dr. Sam Daniels. As for previous ministries already involved, the first step would be to raise their consciousness of the project. This collaboration will allow future information and data flow between the latters and the SLWHC that are primordial for a working system creation.

Communication

Data producers and users – Communication is critical. The SLWHC needs (i) better communication between Ministries and other data producers and (ii) a better communication between data producers (which includes communities) and data users. The first step for wildlife health intelligence is making sure information is coming in from multiple sources and there is a timely way to get information back to people who are making decisions about wildlife management or human-wildlife interactions.

Population - The whole Sri Lankan population is not familiar with the English language. To raise awareness, communication tools should be developed. Translation into the main local languages appears to be an important factor. The most adapted means have to be investigated. Dr. Sam Daniels indicated Internet service is quite diffuse, but I believe the use of radio and meetings could be one feasible and more efficient option.

Education

Health professionals - The launch of the project "Building Research Excellence in Wildlife and Human Health in Sri Lanka" shows that the importance of health professionals has been taken into account. Nevertheless, only four students will be trained thanks to this project, which does not seem sufficient. Professionals should have access to continuous training in order to be aware of their role and the importance of sampling when required. Indeed, 1 submission per month or per year does not appear to me to be enough to build a useful and good quality database.

Population - In a short term objective, population has to be educated as well in the way they have to know they can play a role as an observer and reporter for the wildlife health intelligence project, what type of data are needed and to which institutions they have to report the fact. Education has a primordial role to play in wildlife health intelligence building to make people feel concerned about this project.

For a long term objective, children should be involved into the education process, as mentioned by Dr. Asha Perera, because it will takes decades for those children to be running a wildlife health program. School and animal–related recreational activities could help, but should not be the only tools. Indeed, Kellert (1985) explained "Children who frequently studied animals in school or visited zoos showed surprisingly low knowledge and high negativistic scores, suggesting that these activities are not successful. Children who frequently bird-watched, hunted, or belonged to animal-related clubs were more appreciative, knowledgeable, and concerned about animals, suggesting that direct contact with animals is an important tool in learning and attitude formation." Outdoor activities should have priority.

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APPENDICES

Appendix 1
BC Wildlife health intelligence questionnaire

The goal of this questionnaire is to obtain your opinion on the potential individuals or organizations that might be involved in the collection of data for wildlife health intelligence and on the best means to analyze these data and communicate their significance.

Please fill out the form electronically, following the instructions and return it to <emilie.jamot@vetagro-sup.fr>.

Section 1: Information about you

Q1. Please indicate your primary job responsibilities (Please, put your answer in **bold and blue**) :

1. Wildlife health or disease management
2. Human health or disease management
3. Domestic animal health or disease management
4. Public health
5. Other - *Please specify* _____

Q2. Please indicate for whom you work. (Please, put the right answer in **bold and blue** and add information where applicable)

1. Canadian federal government - *Please specify* Ministry/Department _____
2. BC provincial government - *Please specify* Ministry/Department _____
3. University of BC- *Please specify* the department _____
4. Vancouver Island University- *Please specify* the department _____
5. Private Veterinary practice
6. A non-governmental organization – *Please specify* the name _____
7. Other – *Please specify* _____

Q3. Name of the city where you work: _____

Q4. How often do you use the Internet? Please, put the right answer in **bold and blue**.

1. Every day
2. Every two days
3. Once a week
4. Other- *Please specify* _____

Q5. How would you define your role within the context of wildlife health? Please, put the right answer in **bold and blue**.

1. Decision-maker
2. Directly involved in managing or assessing wildlife health
3. Directly involved in managing or assessing human health
4. Human-Wildlife Conflict Manager
5. Researcher
6. Other - *Please specify* _____
7. None

Q6. What current programs or surveys related to wildlife management, conservation or disease surveillance in BC are you aware of? (Please make a list)

Q7a. Have you heard about wildlife health intelligence previous to this questionnaire ? Please put the right answer in **bold and blue**.

1. Yes - *Please specify in what circumstances* _____
2. No

Q7b. Wildlife health intelligence is briefly described in the questionnaire introduction. What is your opinion or vision of the purpose of wildlife health intelligence ? Please rank these expectations from 1 to 4. (1 is the most important.)

Expectations	**Rank**
To Protect humans from zoonotic diseases	
To Protect humans and domestic animals from animal conflict	
To Protect wildlife from diseases	
To Protect wildlife health and conserve wildlife species	

Section 2: Data collection

Q8. T*able 1* presents possible types of data that are relevant to evaluating wildlife health. We have separated them into health determinants and health outcomes. Please review the table and answer the questions below.

Table 1: Wildlife health determinants and outcomes

HEALTH FACTORS	**PRINCIPLE**	**Species specific METRICS**			**BC data sources - people, groups, institutions or agencies**	**Already existing databases**
		Subject	Characteristics	Data Examples	*Indicate the letter + specification if required*	*Indicate the letter + specification if required*
HEALTH DETERMINANTS						
Physical and Social	HABITAT	Type	Spatial features	Dimensions captures all of specific habitat types		
		Climate	Weather data	Temperature, Humidity		

Environment					and Rainfall variability		
		Air	Air quality		Air pollutant index, Visibility, particles, Rain acidity		
		Soil	Geomorphology		Glaciers, Coastal changes (erosion)		
			Geologic processes		Seismic Activity, Cave air quality		
			Soil Quality		Soil Analysis, Structure, Stability, Permafrost, Fertility		
		Water	Water Body type		Ocean, Sea, River, Lake, Lagoon (brackish water), Reservoir		
			Availability	Quality	Water analysis (minerals, chemicals, microorganisms), Pollution source (sewers, chemicals), Eutrophication, Acidity		
				Quantity	Number of water bodies, Dimensions		
			Accessibility		Location, Water access		
		Food	Food type		Vegetation, Fruits, Prey		
			Availability	Quality	Nutritional analysis, Pollution exposure, Diversity		
				Quantity	Dimensions of vegetation spread, Abundance of the prey		
				Suitabili	Invasive Alien Species		

				ty	presence and depredation		
			Accessibility		Location, Food access		
		Shelter	Shelter type		Vegetation, Cave, Burrow		
			Availability	Quality	Vegetation density, Dimensions, Ground type		
				Quantity	Semi-quantitative or Quantitative methods		
			Accessibility		Location, Access		
		Indicator Species			Status : Endangered vs Abundant		
		Use	Distribution		Location of individuals or herds and their predators		
		Human proximity	Villages/Cities/ Houses/ Campgrounds		Distance, Location, Dimensions		
			Infrastructures (Trails, Roads, Buildings)		Distance, Density, Location, Dimensions, Layout		
		Human presence	Villages/Cities/ People settlements		Distance, Number of inhabitants		
			Land use practice (All year long)		Agriculture type, Forestry, Tourism		
			Habitat fragmentation		Total available habitat dimensions, Fragments dimensions, Distance between fragments		
			Infrastructures (Trails, Roads, Buildings)		Number of persons or vehicle per day, month or year		

			Frequentation			
			Noise/Light Pollution	Hours per day, species affected		
			Wildlife/Human Interactions	Semi-quantitative or Quantitative methods		
Social Environment	WILDLIFE MANAGEMENT	Government policies and laws		Goals, Objectives, Actions, Results, Evaluations and Feedback		
		Non government organization strategy management				
		Health conflict with human and domestic animals		Wildlife-related injuries, Zoonosis, Wildlife-related diseases		
		Depredation		Agriculture, Infrastructures and Neighbourhood damages		
HEALTH OUTCOMES						
Death		Carcass observations* Sampling (passive* and active* surveillance)		Species, Date, Location, Cause of death, Age, Number of dead, Other species		
Longevity		Age distribution		Number of adult, Number of juveniles		
Abnormal Behaviour		Behaviour Observations* Sampling (passive* and active* surveillance)		Species, Clinical signs, Date, Location, Cause, Age, Number of cases, Others species		
Disease						
Stress		Behaviour		Laying, Standing, Running,		

			Walking		
	Sampling (Feces, Hair, Blood)		Stress Hormones		
Productivity	Reproduction	Age distribution	Number of adult, Number of offspring		
	Abundance		Number of individuals		
	Genetic diversity	Sampling (Feces, Hair, Blood)	Genetics		
	Resources	Human use of Wildlife	Hunting, Poaching records Numbers of individuals used for cultural or work use		
Disability	Mobility	Behaviour Injuries	Standing, Running, Walking		
	Activity		Hunting, Feeding, Watering, Reproducing		
Nutritional Status	Body condition		Rump fat and Rib fat measurement		
* *Observation:* The action of observing carcasses, signs of disease or abnormal behaviour and reporting the observation to some responsible agency *Passive surveillance*: This means opportunistic sampling on dead animal *Active surveillance*: This means to go out and collect samples for a particular disease					

Q8a. Is *Table 1* complete? Does it include all the categories of health determinants and health outcomes of major importance? Please review the *Table 1* carefully and make comments on its completeness in the box below

Q8b. We would like your opinion on who or what agency might have data (now or in the future) or help with data collection for each of the categories of health data listed. Please review instructions below to fill out *Table 1*.

Below we provide a list of possible people and agencies that may serve as sources (A-X). For each category, please list any or all that may be sources of data. If none apply, please, leave the cell blank.

A. Wildlife agency veterinarian
B. Private practice veterinarians
C. Provincial or federal park employees
D. Independent biologists/researchers
E. Canadian Food Inspection Agency staff
F. Specific group of volunteers
G. The general public
H. First Nations members
I. Trappers
J. Hunters
K. Anglers
L. Tourists/wildlife viewers (recreationalists)
M. Geocachers, cavers
N. Heliskiing and helihiking companies
O. Guide outfitting industry
P. Back country horseback riders
Q. Road maintenance crews
R. Bird watchers
S. Wildlife rehabilitation community
T. Naturalist community
U. Farmers and ranchers, game farmers
V. Conservation groups
W. NGO - *Please specify the name:* W. _____
X. Other- *Please specify* X. _____

We have also provided a list of Ministries (Z1-Z11) below because some of them might have some information. If you know which Ministry might have data for a category, please list it as well.

BC Ministry – *Please specify*

Z1	Aboriginal Relations and Reconciliation
Z2	Agriculture
Z3	Community, Sport and Cultural Development
Z4	Energy and Mines
Z5	Environment
Z6	Forests, Lands and Natural Resource Operations
Z7	Health
Z8	International Trade
Z9	Jobs, Tourism and Skills Training
Z10	Natural Gas Development
Z11	Transportation and Infrastructure

Additional comments (optional):

Q9. Please list the top 5 pieces of information from the table that you believe to be the most reliable, feasible to collect and consistently collectable (repeatable)

1. _____
2. _____
3. _____
4. _____
5. _____

Additional comment (optional):

Q10. What are the primary limitations to collecting the other data in a reliable and repeatable manner?

Q11. In *Table 1,* Health factors are separated into health determinants and health outcomes. In your opinion, if we have to focus on only three factors at first, what should be the three essentials we could quickly and reliably watch to evaluate wildlife health? Choose at least one health determinant.

- _____
- _____
- _____

Explain your choice:

Q12. In your opinion, what should be the 5 wildlife species of first priority to be included in wildlife health intelligence in BC? List them and explain why.

Rank	Species	Reason
1		
2		
3		
4		
5		

Section 3: Data analysis and application

Q13. Do the skills and/or the capacity to perform the following data analysis function currently exist in BC? Please, answer by Yes or No.

1. Meeting with all principles stakeholders and potential participants _____
2. Mapping _____
3. Making graphics to follow factors evolution_____
4. Statistics for indicator change detection _____
5. Modeling _____

Additional comment (optional):

Q14. Can you propose additional data analysis function to turn data into understandable information for decision-makers and those interested in the data? What are they?

Section 5: Gaps and Needs

Q15. Can you identify some obvious gaps for the feasibility of a wildlife health intelligence program in BC?

Q16. What needs to be done to close these gaps within 1-2 years?

Q17. What needs to be done to close these gaps within 5-10 years?

END

Thank you so much for participating ! Your feedback is essential for the implementation of a relevant and working wildlife health intelligence program for BC.

Appendix 2

WILDLIFE HEALTH INTELLIGENCE QUESTIONNAIRE - FOR BC – CENTRE FOR COASTAL HEALTH

INTRODUCTION

The goal of this questionnaire is to gather local knowledge to help the Centre for Coastal Health (CCH) and its partners develop the concept of a sustainable wildlife health intelligence network that is capable of detecting and assessing "signals" at the wildlife-human interface. We would like to learn if these signals or signs can forecast emerging disease risks to humans from wildlife or to wildlife from humans in order to inform management decisions to protect and promote human and wildlife health. So – ***can we predict disease events and risks before they occur?***

THE ISSUE:

The rapidly changing patterns of human and animal diseases and their rising socioeconomic consequences around the world are a defining condition of the 21st Century. Recent analysis of the global emergence of new human and animal diseases shows that their emergence is concentrated in geographical areas characterized by high density of people, domestic animals and wildlife, and by rapidly changing environmental conditions. The analysis identified pathogens in wild animals as the most important source of emerging infectious diseases (Jones *et al.* 2008, Woolhouse and Gowtage-Sequeria 2005).

The British Columbia (BC) Wildlife Health Program tracks general health issues and performs surveillance on some wildlife diseases considered to be of high priority. To enhance the efficacy and the usefulness of this program, the human population health approach can serve as a model. This human health approach is based on how different factors and conditions interact to influence population health and uses resulting information for decision-making (Public Health Agency Canada, 2012). The Public Health Agency of Canada considers that health is determined by complex interactions between social factors, the physical environment and individual behaviors. These factors are referred to as "determinants of health". (Public Health Agency Canada, 2011).

Therefore, to monitor health (of any species), it is important to observe health outcomes like nutritional state, reproduction, longevity and diseases, to note factors that affect animal vulnerability to harm and ability to cope (or health determinants) and to track hazards that could affect their health. Health determinants are always present and always changing in the physical and social environments of animals (habitat, food, harassment, hunting).

WHAT IS HEALTH INTELLIGENCE ? : Health Intelligence may be defined as a summary of methods used to collect, analyze, interpret and then timely report this information in order to make it usable, for example for decision-makers to make decisions that could improve the health of the population studied.

HOW CAN HEALTH INTELLIGENCE ENHANCE THE BC WILDLIFE HEALTH PROGRAM ? :

(1) Provides information on health, not just disease ;

(2) Includes the collection of information on diseases and their effects plus the risks and capacity of populations to deal with them.

(3) Provides knowledge on interactions between humans and wildlife to better understand present and emerging risks ;

(4) By collecting more diverse information, the intelligence-based system can succeed in delivering early warnings about potential threats to population health (Yde *et al.*, 2012);

(5) Interprets the information to enable timely management actions to protect and promote health. This is in contrast to surveillance where the goal is early detection of disease to quickly minimize their effects and reduce the impact. Health intelligence and surveillance are clearly related and complementary activities.

WHY A QUESTIONNAIRE ? : The CCH is an independent, non-profit organization located in Nanaimo's Vancouver Island University. CCH's mission is to identify and understand the interactions of human, animal and environmental health. We are interested in exploring the concept of a wildlife health intelligence network that could be implemented in BC to assist the BC Wildlife Health Program and other agencies interested in wildlife and human health. This questionnaire is part of a Master degree program for Emilie Jamot, a veterinarian in training from the veterinary college at the University of Lyon. Participation is voluntary. We do not wish to collect any personal information but rather only use your expert knowledge to better understand how potential wildlife health intelligence information is collected, analyzed and communicated in BC. The results will be part of Ms Jamot’s thesis research

Appendix 3

List of the different data collection actors in BC proposed by wildlife key informants

See caption below

HEALTH FACTORS	PRINCIPLE	Species specific METRICS			BC data sources - people, groups, institutions or agencies	Already existing databases
		Subject	Characteristics	Data Examples	*Indicate the letter + specification if required*	*Indicate the letter + specification if required*
HEALTH DETERMINANTS						
Physical and Social Environment	HABITAT	Type	Spatial features	Dimensions captures all of specific habitat types	C,D,F,H,I,J,K,L,M,O,P,R,T,U,V	Z2, 4,5,6,10, 11
		Climate	Weather data	Temperature, Humidity and Rainfall variability	D, X: Insurance companies	Z2,5 6,11 ; X : Agriculture and Agri-Food Canada, Environment Canada
		Air	Air quality	Air pollutant index, Visibility, particles, Rain acidity	D, W : Pollution Probe, David Suzuki Foundation, etc	Z5, 7
		Soil	Geomorphology	Glaciers, Coastal changes (erosion)	D, Q, X : Commercial boat operators (fishing, fish farms, transport)	Z4,5,6,11; X: Fisheries and Oceans Canada(Coast Guard)
			Geologic processes	Seismic Activity, Cave air quality	C, D, M	Z4,5,6 ; X : Environment Canada
			Soil Quality	Soil Analysis, Structure, Stability, Permafrost, Fertility	D, U, V	Z2,6 X: Agriculture and Agri-Food Canada, Natural Resources Canada
		Water	Water Body type	Ocean, Sea, River, Lake, Lagoon (brackish water), Reservoir	C, D	Z3,4,5,6 ; X : Fisheries and Ocean Canada
			Avail Quality	Water analysis (minerals,	D, V	Z2,4,5 W: Environment

			abilit y		chemicals, microorganisms), Pollution source (sewers, chemicals), Eutrophication, Acidity		Canada, Fisheries and Oceans Canada, Natural Resources Canada
				Quantity	Number of water bodies, Dimensions	D,V	Z2,4,5,6 X: Environment Canada, Fisheries and Oceans Canada, Natural Resources Canada
			Accessibility		Location, Water access	H,I,J,K,L,M,O,V	Z2,3,4,5,6,9,11
		Food	Food type		Vegetation, Fruits, Prey	C,D,H,I,J,K,O,R,T,U,V,X : Forestry industry	Z5,6
			Avail abilit y	Quality	Nutritional analysis, Pollution exposure, Diversity	C,D,H,I,J,K,O,R,T,U,V,X : Forestry industry	Z5,6
				Quantity	Dimensions of vegetation spread, Abundance of the prey	C,D,H,I,J,K,O,R,T,U,V, X : Forestry industry	Z5,6
				Suitabilit y	Invasive Alien Species presence and depredation	C,D,H,I,J,K,O,R,T,U,V,X : Forestry industry, Invasive Species Council of BC	Z5,6
			Accessibility		Location, Food access	C,D,H,I,J,K,L,M,O,P,Q,R,T,U,V,X : Forestry industry	Z5,6
		Shelter	Shelter type		Vegetation, Cave, Burrow	C, D,V	Z5
			Avail abilit y	Quality	Vegetation density, Dimensions, Ground type	C,D,V	Z5, 6
				Quantity	Semi-quantitative or Quantitative methods	C,D,V	Z5, 6
			Accessibility		Location, Access	C,D,H,I,J,K,L,M,O,P,Q,R,T,U,V,X : Forestry industry	Z5,6
		Indicator Species			Status : Endangered vs Abundant	C, D, H, I, J, K, R, V; X : COSEWIC for species at risk, Z5 (Conservation Data Centre)	Z5
		Use	Distribution		Location of individuals or herds and their predators	C, D, H, I, J, K, R, V; X : COSEWIC for species at risk,	Z5,6

					Z5 (Conservation Data Centre)	
		Human proximity	Villages/Cities/Houses/ Campgrounds	Distance, Location, Dimensions	V	Z1,3,5,6,9
			Infrastructures (Trails, Roads, Buildings)	Distance, Density, Location, Dimensions, Layout	V	Z4,5,6,11
		Human presence	Villages/Cities/People settlements	Distance, Number of inhabitants	D (social science)	Z1,7 ; X: Statistics Canada and BC Stats
			Land use practice (All year long)	Agriculture type, Forestry, Tourism	C, D (remote sensing geography)	Z1,2,3,4,5,6,10,11; X:Natural Resources Canada
			Habitat fragmentation	Total available habitat dimensions, Fragments dimensions, Distance between fragments	D (remote sensing geography)	Z5,6 ; X : Natural Resources Canada,
			Infrastructures (Trails, Roads, Buildings) Frequentation	Number of persons or vehicle per day, month or year	D (remote sensing, demography/human geography)	Z1,7 ; X: Statistics Canada and BC Stats
			Noise/Light Pollution	Hours per day, species affected	D (if there are any such data), V	
			Wildlife/Human Interactions	Semi-quantitative or Quantitative methods	C, H, O, U	Z1,2,4,5 (Conservation Officer Service database),6,7
Social Environment	WILDLIFE MANAGEMENT	Government policies and laws		Goals, Objectives, Actions, Results, Evaluations and Feedback	C,I,J,K,L,M,O,T,U,V; X : COSEWIC for species at risk	Z1,4,5,6 ; X: Environment Canada-Canadian Wildlife Service (CWS) (Wildlife Act)
		Non government organization strategy management			V, X : BC Wildlife Federation	
		Health conflict with human and domestic animals		Wildlife-related injuries, Zoonosis, Wildlife-related diseases	A, C,D, E, H, O , Z5 (Conservation Officer Service)	Z-5 (Conservation Officer Service database),6,7 ; X: Health Canada-First Nation and Inuit Health Branch, Centre for Disease Control

					and Prevention, Animal Health Laboratory Database
		Depredation	Agriculture, Infrastructures and Neighbourhood damages	D, U, X: Insurance Industry, BC Cattlemen's Association, Z5 (Conservation Officer Service)	Z-2,5,10,11
HEALTH OUTCOMES					
Death		Carcass observations* Sampling (passive* and active* surveillance)	Species, Date, Location, Cause of death, Age, Number of dead, Other species	All except E, F,N	Z-2 (Animal Health Centre),5 (Wildlife Health Program),6,11, CCWHC
Longevity		Age distribution	Number of adult, Number of juveniles	C,D,V, Z6 (Inventory programs)	Z-5 (Wildlife Health Program),6
Abnormal Behaviour		Behaviour Observations* Sampling (passive* and active* surveillance)	Species, Clinical signs, Date, Location, Cause, Age, Number of cases, Others species		
Disease				All except E, F,N	Z-2,5 (Wildlife Health Program),6,11
Stress		Behaviour	Laying, Standing, Running, Walking	All except E, F,N	Z-2,5 (Wildlife Health Program),6,11
		Sampling (Feces, Hair, Blood)	Stress Hormones	A, C, D	Z-5 (Wildlife Health Program)
Productivity		Reproduction	Age distribution	Number of adult, Number of offspring	C, D, O, V; X : COSEWIC for species at risk	Z-5 (Wildlife Health Program),
		Abundance		Number of individuals	C,D,O,V; X : COSEWIC for species at risk	Z-5
		Genetic diversity	Sampling (Feces, Hair, Blood)	Genetics	D, X : COSEWIC for species at risk	Z-5(Wildlife Health Program),6
		Resources	Human use of Wildlife	Hunting, Poaching records Numbers of individuals used for cultural or work use	C, E (inspected commercial harvests), H, O, V; X : Hunter and Trapper Organizations in NU, NT	Z-5 (Conservation officer service Database),6 ; X : Environment Canada/CWS enforcement for federal species

Disability	Mobility	Behaviour Injuries	Standing, Running, Walking	All except E, F,N	Z-2,5,6,11
	Activity		Hunting, Feeding, Watering, Reproducing	All except E, F,N	Z-2,5,6,11
Nutritional Status	Body condition		Rump fat and Rib fat measurement	A, D	Z-5

* *Observation:* The action of observing carcasses, signs of disease or abnormal behaviour and reporting the observation to some responsible agency
Passive surveillance: This means opportunistic sampling on dead animal
Active surveillance: This means to go out and collect samples for a particular disease

Caption :

List of potential actors in data collection :

A-Wildlife agency veterinarian
B-Private practice veterinarians
C-Provincial or federal park employees
D-Independent biologists/researchers
E-Canadian Food Inspection Agency staff
F-Specific group of volunteers
G-The general public
H-First Nations members
I-Trappers
J-Hunters
K-Anglers
L-Tourists/wildlife viewers (recreationalists)
M-Geocachers, cavers
N-Heliskiing and helihiking companies
O-Guide outfitting industry
P-Back country horseback riders
Q-Road maintenance crews
R-Bird watchers
S-Wildlife rehabilitation community
T-Naturalist community
U-Farmers and ranchers, game farmers
V-Conservation groups
W-NGO - *Please specify the name:* W.
X-Other- *Please specify* X.

List of potential Ministries of British Columbia involved :

Z1-Aboriginal Relations and Reconciliation
Z2-Agriculture
Z3-Community, Sport and Cultural Development
Z4-Energy and Mines
Z5-Environment
Z6-Forests, Lands and Natural Resource Operations
Z7-Health
Z8-International Trade
Z9-Jobs, Tourism and Skills Training
Z10-Natural Gas Development
Z11-Transportation and Infrastructure

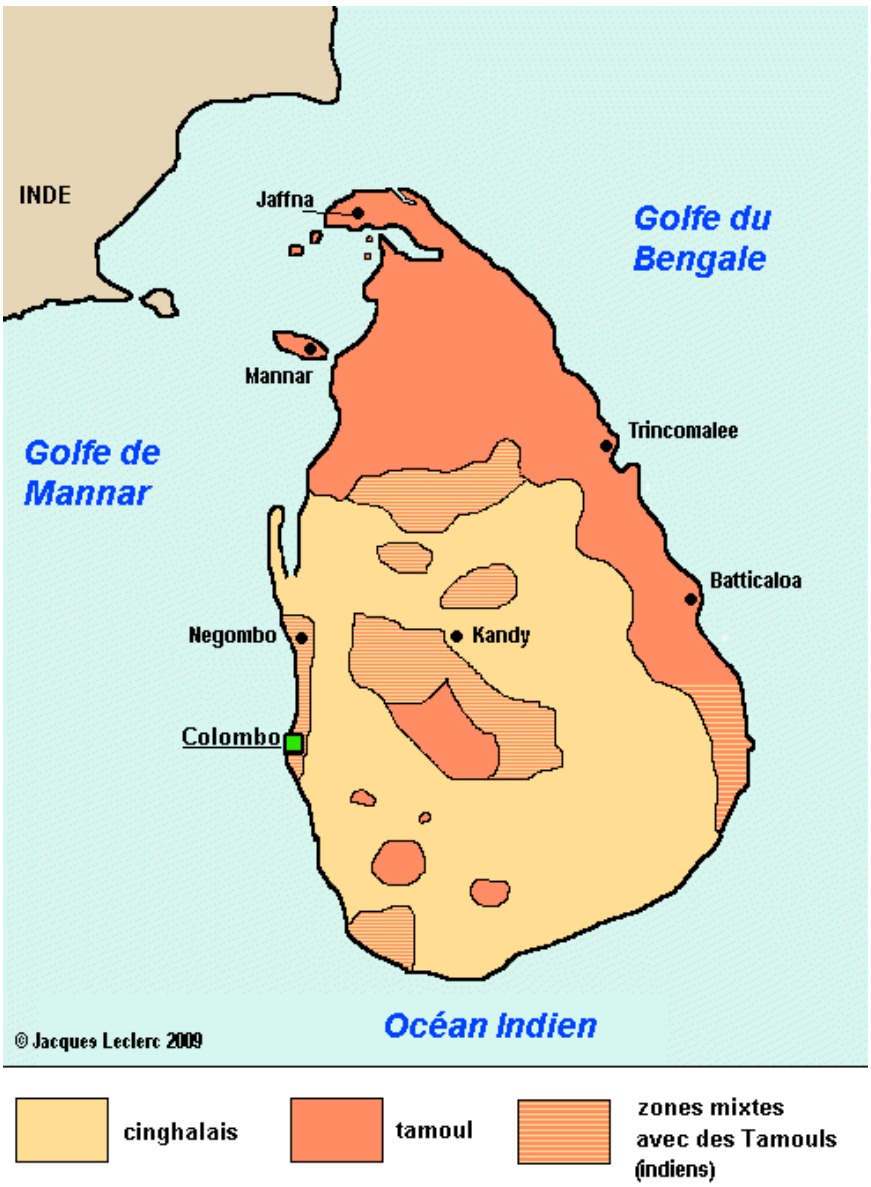
Abbrevations :

COSEWIC - Committee on the Status of Endangered Wildlife in Canada

CWS - Canadian Wildlife Service

Appendix 4

Location of the Tamil and the Sinhalese people in Sri Lanka (UNESCAP)

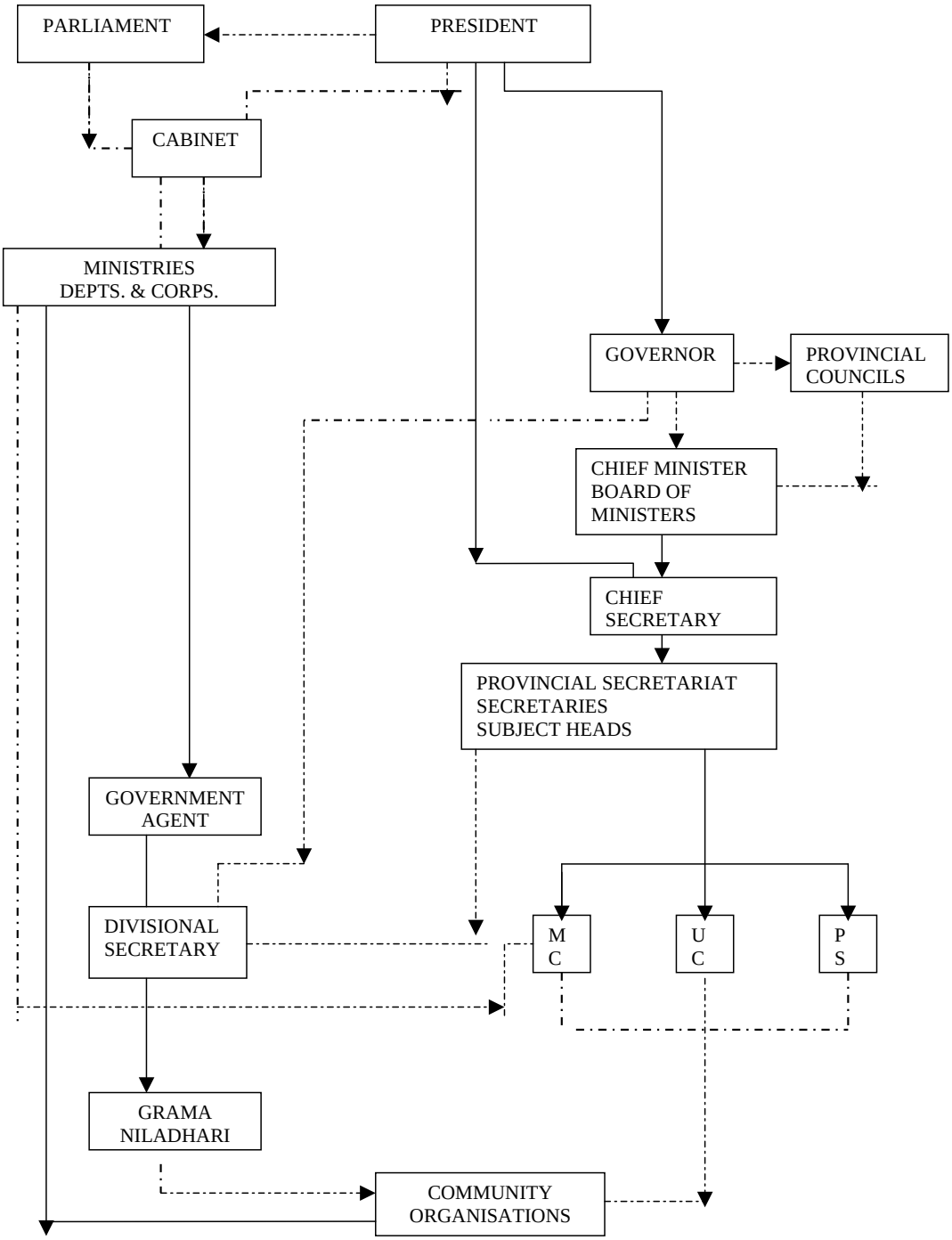


Appendix 5

The Sri Lankan Provincial organization (UNESCAP)

Appendix 6

Structure of the Sri Lankan government administration (UNESCAP)



MC : Municipal council
UC : Urban council
PS : *Pradeshiya Sabhas*

Appendix 7

Diagnostic capabilities in Sri Lanka (Sawford *et al.*, 2011)

Location	Diagnostic capabilities	Confirmable condition (if applicable)
Field offices	Clinical examination Gross post mortem examination California Mastitis Test* Microscopy (+/- stain)*	 Mastitis Blood-borne parasites
VICs	California Mastitis Test Microscopy (+ stain) and fecal flotation Aerobic bacterial culture Antibiotic sensitivity testing Rose Bengal plate agglutination test Rapid antigen detection	Mastitis Blood-borne parasites, intestinal parasites Bacterial infection Bacterial drug resistance Brucellosis Highly pathogenic avian influenza
VRI	California Mastitis Test Microscopy (+ stain) and fecal flotation Aerobic and anaerobic bacterial culture Antibiotic sensitivity testing Histopathology Complement fixation test Milk ring test Antigen detection enzyme-linked immunosorbent assay Enzyme-linked immunosorbent assay Reverse transcription-polymerase chain reaction Pathogen isolation by egg inoculation Serology	Mastitis Blood-borne parasites, intestinal parasites Bacterial infection Bacterial drug resistance Brucellosis Brucellosis Foot and mouth disease Classical swine fever Highly pathogenic avian influenza Newcastle disease Infectious Bursal Disease Infectious Bronchitis Reovirus infection Infectious laryngotrachitis
*Only select offices have these diagnostic capabilities.		