

# 'Environmental' surveillance for zoonoses

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PROTECTING CANADIANS FROM ILLNESS



Public Health  
Agency of Canada

Agence de la santé  
publique du Canada

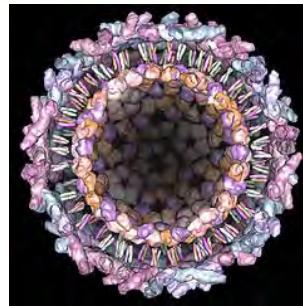
Canada

# Zoonoses

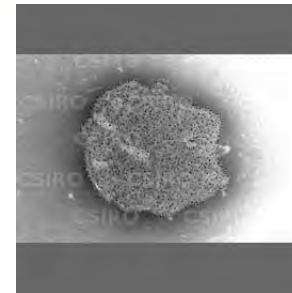
- Infectious diseases transmitted from animals to humans
- In some cases zoonoses are transmitted, with limited efficiency, from human to human
- In some cases zoonoses can evolve to be efficiently transmissible human-to-human (malaria, SARS, HIV, pandemic influenza)
- Transmission by all routes – meat, contamination of water and produce, direct contact, air-borne, vector-borne
- All animals involved:
  - » Domesticated livestock:
    - Enterics: E. coli, Salmonella, Cryptospridium, Campylobacter, Giardia
    - TB, Brucellosis, Zoonotic Influenza, Toxoplasmosis, Trichinellosis, Leptospirosis, Q fever
  - » Wildlife:
    - Rabies, Lyme, WNV, EEE, St Louis, Toxoplasmosis, Trichinellosis, Baylisascaris, Tularaemia, Relapsing fever, Bartonella, Q fever, Hantavirus, Leptospirosis, Echinococcus, Zoonotic influenza
  - » Companion animals (and via pet foods and treats):
    - Rabies, Enterics, Psittacosis, MRSA, Toxocariasis, Leptospirosis, Bartonella, Echinococcus



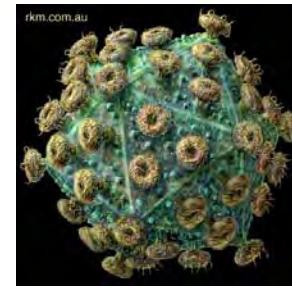
Lyme



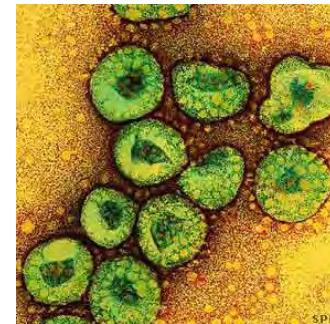
Chikungunya



Hendra



HIV



SARS

Most (75%) EIDs are zoonoses

Woolhouse ME, Gowtage-Sequeria S. 2005 EID

Most affecting Canada have been zoonoses that emerged elsewhere in the world

(HIV, SARS, WNV, pH1N1, Lyme)



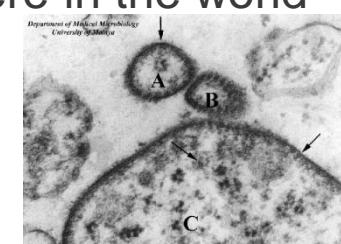
RVF



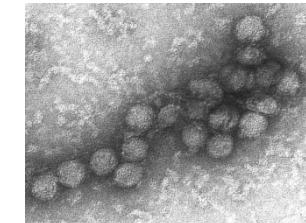
Chikungunya vector



Lyme vector



Nipah

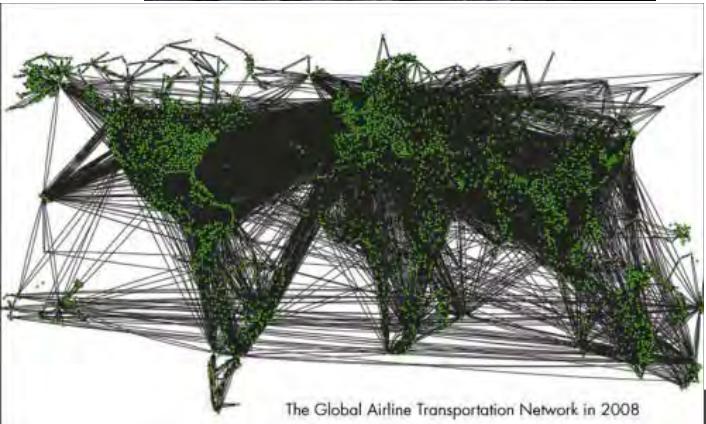
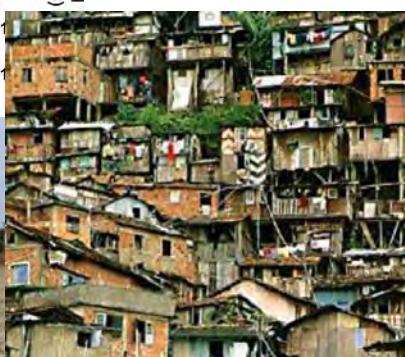
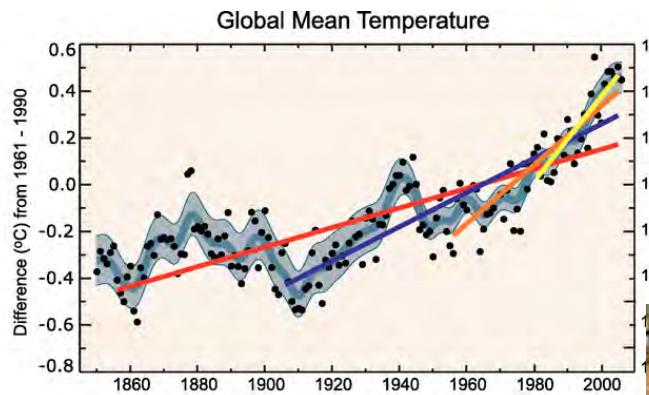


WNV

# Emergence/re-emergence of infectious diseases

1. Human awareness (Lyme, SARS)\*
2. Introduction of exotic pathogens/vectors into existing suitable host/vector/human-contact ecosystem (SARS, West Nile)\*
3. Geographic spread from neighbouring endemic areas (Lyme, Rabies)\*
4. Ecological change causing endemic disease of wildlife/domesticated animals to ‘spill-over’ into humans/domesticated animals (Hendra, Nipah, Hantavirus, RVF)\*
5. True ‘emergence’: evolution and fixation of new, pathogenic genetic variants of previously benign microorganisms (High Path Zoonotic Influenzas)

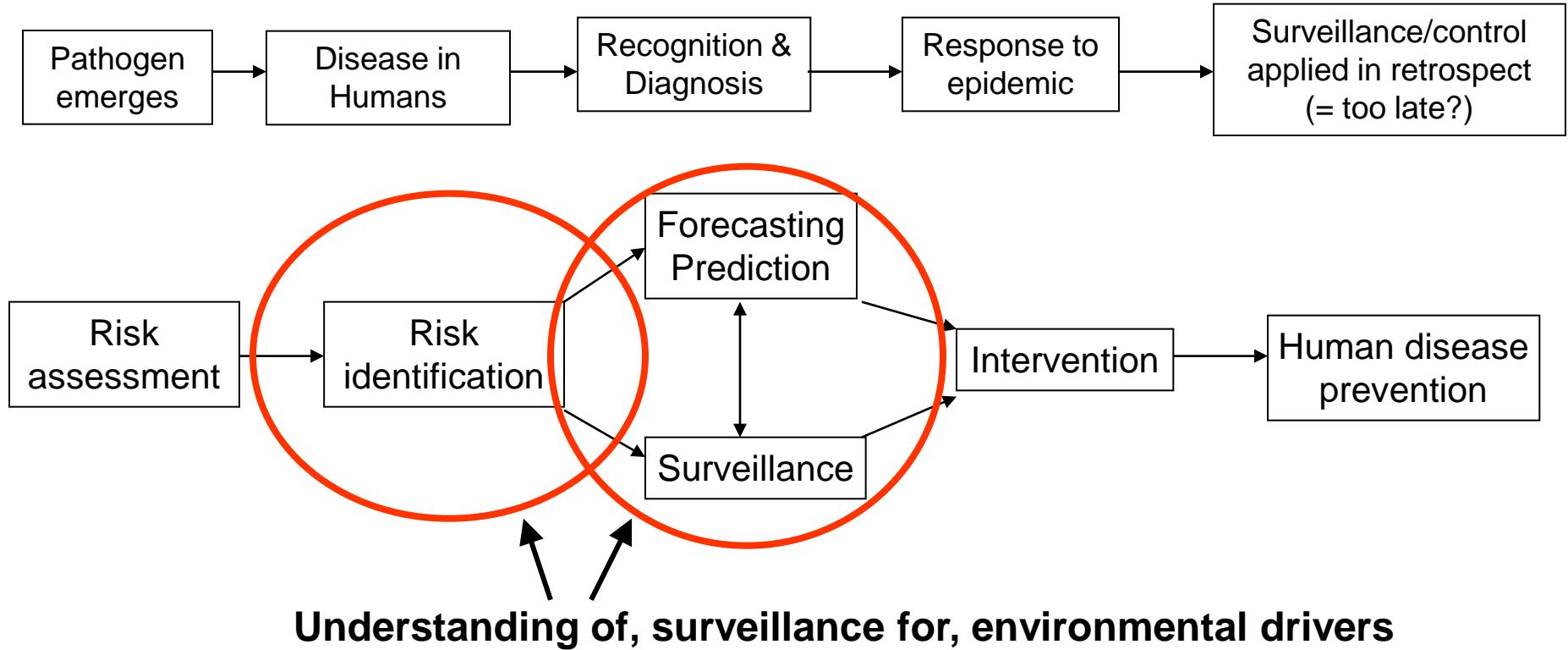
# Drivers for disease emergence and spread



**Emergence.....Spillover....Spread**



# Predicting, identifying and preventing versus responding



# Defining surveillance

WHO: “the continuous, systematic collection, analysis and interpretation of health-related data needed for the planning, implementation, and evaluation of public health practice, to:

- serve as an early warning system for impending public health emergencies;
- document the impact of an intervention, or track progress towards specified goals; and
- monitor and clarify the epidemiology of health problems, to allow priorities to be set and to inform public health policy and strategies.

By definition, surveillance systems include the capacity for data collection and analysis, as well as the timely dissemination of information to persons or group of persons who can undertake effective prevention and control interventions related to specific health outcomes.”

# Qualities of surveillance systems

CDC: Surveillance systems should be:

- Needed (i.e. respond to an event/issue of sufficient importance)
- Useful (i.e. contributes to prevention and control of adverse health events)
- Well designed:
  1. Simplicity: Surveillance systems should be as simple as possible while still meeting their objectives.
  2. Flexibility: A flexible surveillance system can adapt to changing information needs or operating conditions with little additional cost in time, personnel, or allocated funds.
  - 3 Acceptability: The willingness of individuals and organizations to participate in the surveillance system.
  4. **Sensitivity:** The proportion of cases of a disease or health condition detected (or ability to detect epidemics) by the surveillance system can be evaluated.
  5. **Predictive value positive:** The proportion of persons identified as having cases who actually do have the condition under surveillance.
  6. **Representativeness:** The quality and usefulness of the data collected, which depends on its completeness and validity.
  7. **Timeliness:** The speed or delay between steps in a surveillance system

# What does 'environmental' surveillance for zoonoses comprise?

- For the purposes of this talk, I use the term 'environmental' surveillance to define surveillance systems that use data outside of human cases to achieve one or more of the WHO objectives for a surveillance system.
- Sources of data could be:
  - » Pathogen transmission materials:
    - Arthropod vectors
    - Ingested products (water, food)
  - » Sources of pathogen contamination of transmission materials
    - Infected food-producing animals that directly contaminate food
    - Animals that contaminate water supplies and produce
    - Animal reservoirs (i.e. sources) of vector-borne zoonoses
  - » Animal reservoirs (livestock, pets, wildlife) of directly transmitted zoonotic diseases
  - » Animal sentinels (livestock, pets, wildlife) for pathogens and vectors whether or not they are reservoirs (NB wider implications beyond zoonoses)
  - » Samples or other data that act as a proxy for risk from zoonoses
    - Sampling of pathogens from the environment (fields, abattoirs, plants, barns)
    - Weather data (as a proxy for risk of vector-borne diseases, water-borne diseases)

## 'Environmental' versus human case surveillance for zoonoses

- Human case surveillance should occur simultaneously to validate and/or evaluate environmental surveillance
- It is a fundamental activity of public health to 'test' 'environmental' samples/proxies to identify risk **before human cases occur** and to intervene on the basis of 'test' results:
  - » Meat/food inspection
  - » Water quality testing
  - » TB, Brucellosis eradication in livestock
  - » Mosquito and sentinel animal surveillance for vector-borne zoonoses

## ‘Environmental’ versus human case surveillance for zoonoses

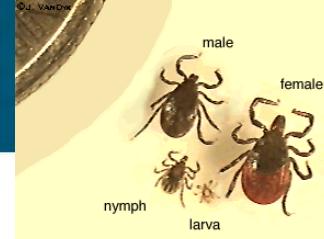
- Environmental surveillance identifies where and when risk is occurring i.e. “serves as an early warning system for impending public health emergencies”
- Environmental surveillance lends itself to research to “clarify the epidemiology of health problems”
- Environmental surveillance can monitor the effectiveness of interventions, when these are targeted at reducing environmental risk
- Environmental surveillance can perform better than human case surveillance:
  - » Timeliness – once human cases occur – it’s too late
  - » Sensitivity – zoonoses always more abundant/prevalent in hosts, vectors than in humans
  - » Representativeness – zoonoses occur where their hosts and vectors are – not where people are
  - » Acceptability – non-invasive regarding humans
- Surveillance signals are detected at the point where interventions often need to be applied – mosquito control, water treatment, livestock culling

# Limitations of, problems with, ‘environmental’ surveillance

- Does not identify human demographics at risk
- Specificity – needs careful analysis to link detection of pathogens in the ‘environment’ and risk to human health
- Simplicity – this is a ‘One Health’ approach but requires multiple actors working for health objectives, e.g. Lyme in NS, proposed surveillance for zoonotic influenzas in swine
- Acceptability – interventions may need to be undertaken and/or paid for by non-public health actors, e.g. zoonoses from livestock
- Too timely – public health is used to acting in response to a ‘body count’
- Resistance and lack of knowledge in PH community

# EXAMPLES

# Surveillance for Lyme disease risk



- Bacterial infection caused by *Borrelia burgdorferi*
- Transmitted amongst wild animals hosts (rodents, squirrels, birds etc) by ticks (*Ixodes scapularis* and *I. pacificus*), which also transmit infection to humans
- Causes mild disease initially: flu-like with classic skin lesion (erythema migrans)
- Then develops into more severe disease – Lyme arthritis, neuroborreliosis and heart block
- Risk occurs where ticks occur in woodland and peri-woodland areas
- Emerging in Canada due to spread of the tick *Ixodes scapularis* from the US
- Surveillance designed to trigger interventions for the population at risk:
  - » Information on personal protection to the public - LD cases prevented
  - » Information to medical practitioners - LD cases are treated early in disease when it is easy to treat, and impacts on patient and health care system are minimal

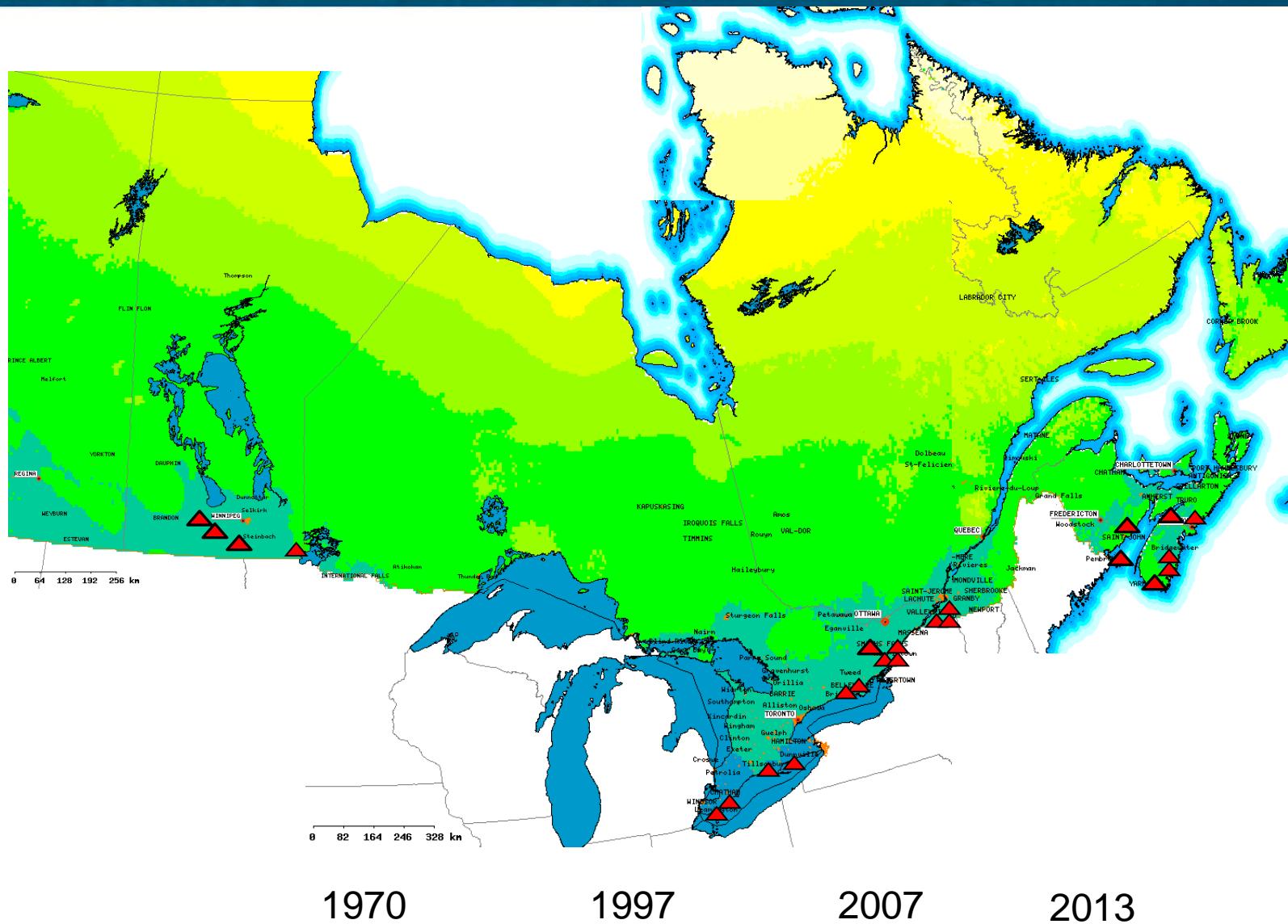


# Active field surveillance is the ‘gold standard’

- Capture of rodent hosts of tick and bacterium and flagging for host-seeking ticks
- Usually undertaken in response to passive surveillance or human cases



# Reproducing populations of *I. scapularis* in Canada



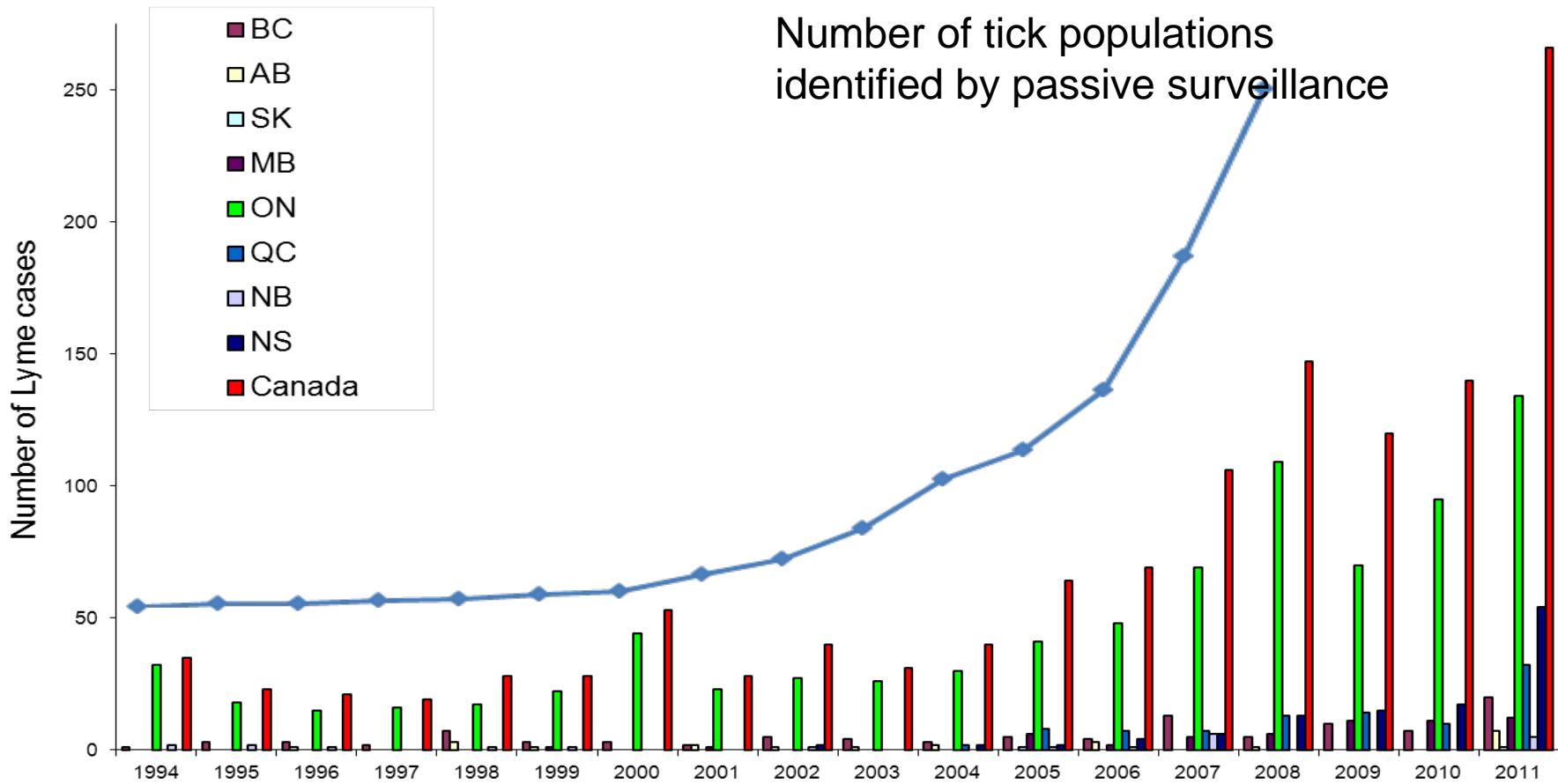
# Passive tick surveillance in Canada

- Passive surveillance for *I. scapularis* has occurred in Canada since 1990
- Ticks collected from patients at, submitted from, medical and veterinary clinics
- Spatial resolution used in the following is Census Sub-Division (CSD)
- Ticks species identification and PCR for the Lyme disease spirochete *Borrelia burgdorferi* at PHAC National Microbiology Lab (NML)
- Passive surveillance data:
  - Provide a long dataset (1990 to present)
  - Have a wide geographic coverage
  - Are sensitive...
  - ...but non-specific due to detection of bird-dispersed ticks (particularly by ticks from dogs)
- We have developed methods to analyse the data to improve specificity



# Temporal occurrence of Lyme disease risk

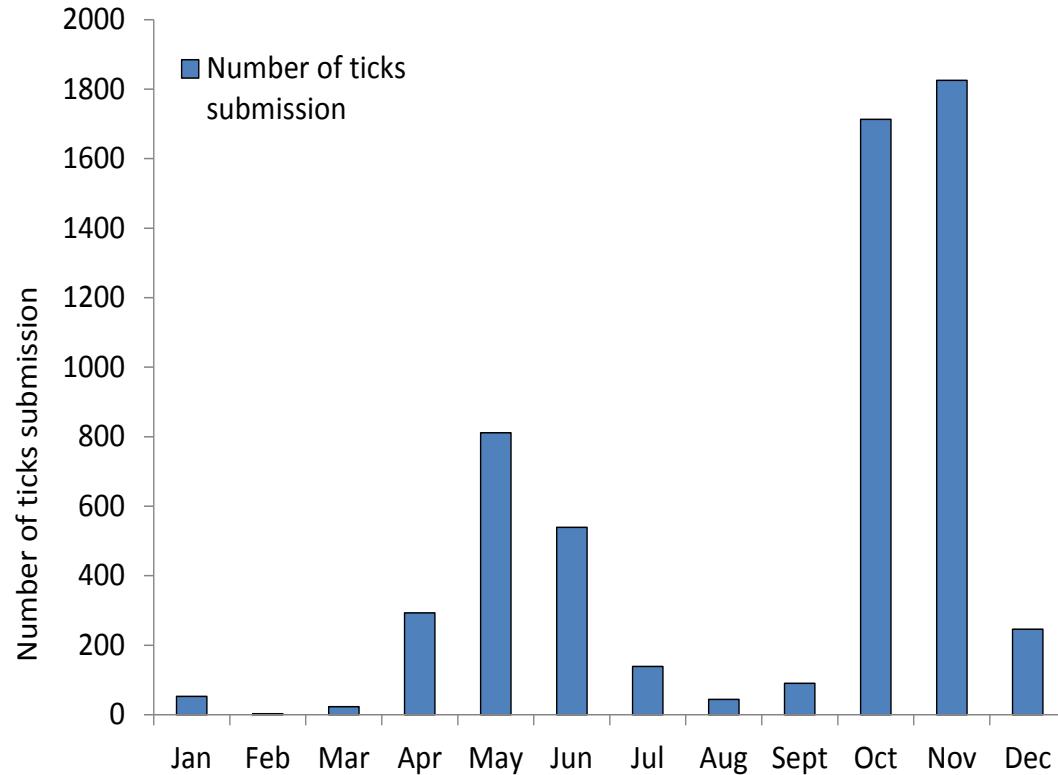
- Long term multi-annual trends – identifying risk ahead of human cases



Ogden et al., 2010 Environ Health Perspect; 2013 J Appl Ecol; Leighton et al., 2012 J Appl Ecol

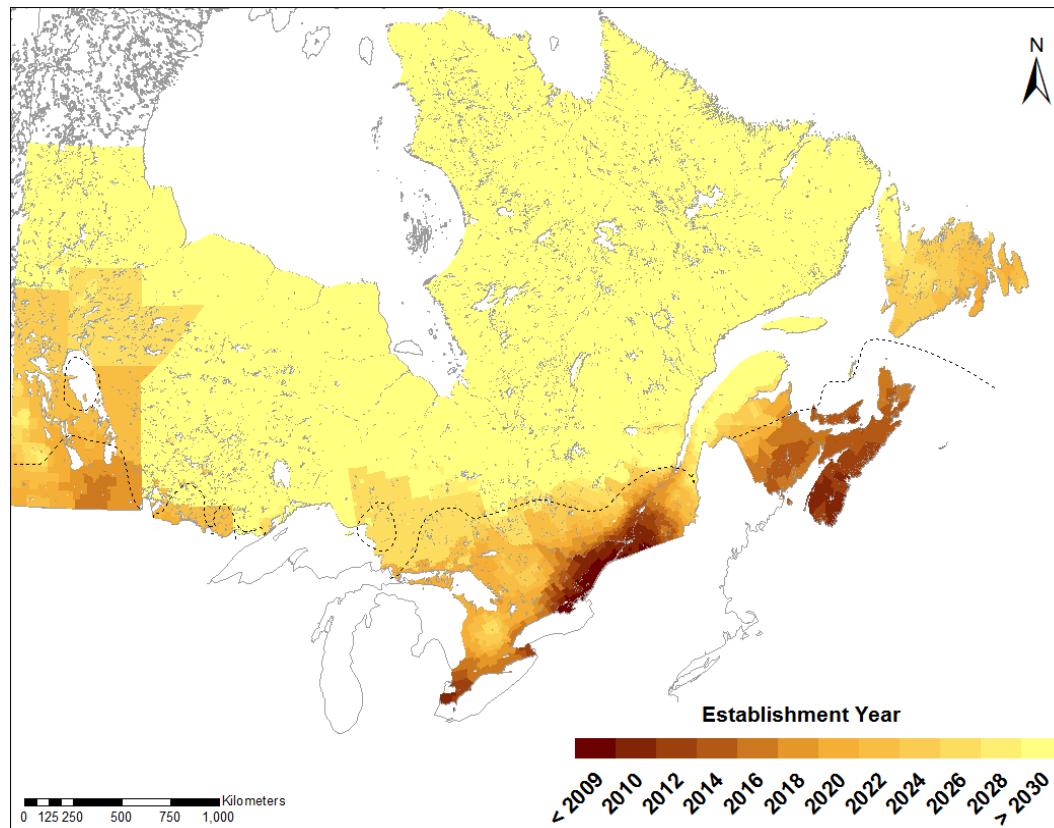
# Temporal occurrence of Lyme disease risk

- Short-term seasonal trends in risk



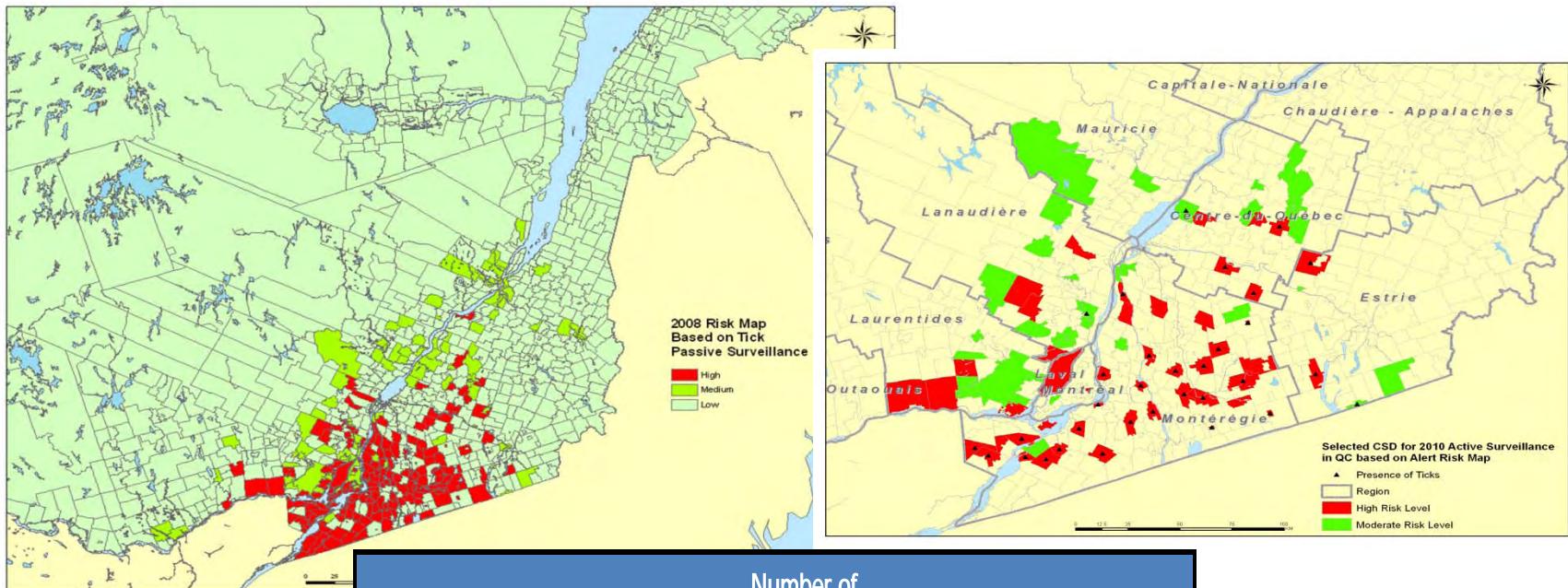
# Spatial occurrence of Lyme disease risk - National scale

- For most wildlife-borne zoonoses the population at risk is defined by the geographic occurrence of the zoonosis



Leighton et al., 2012 J Appl Ecol

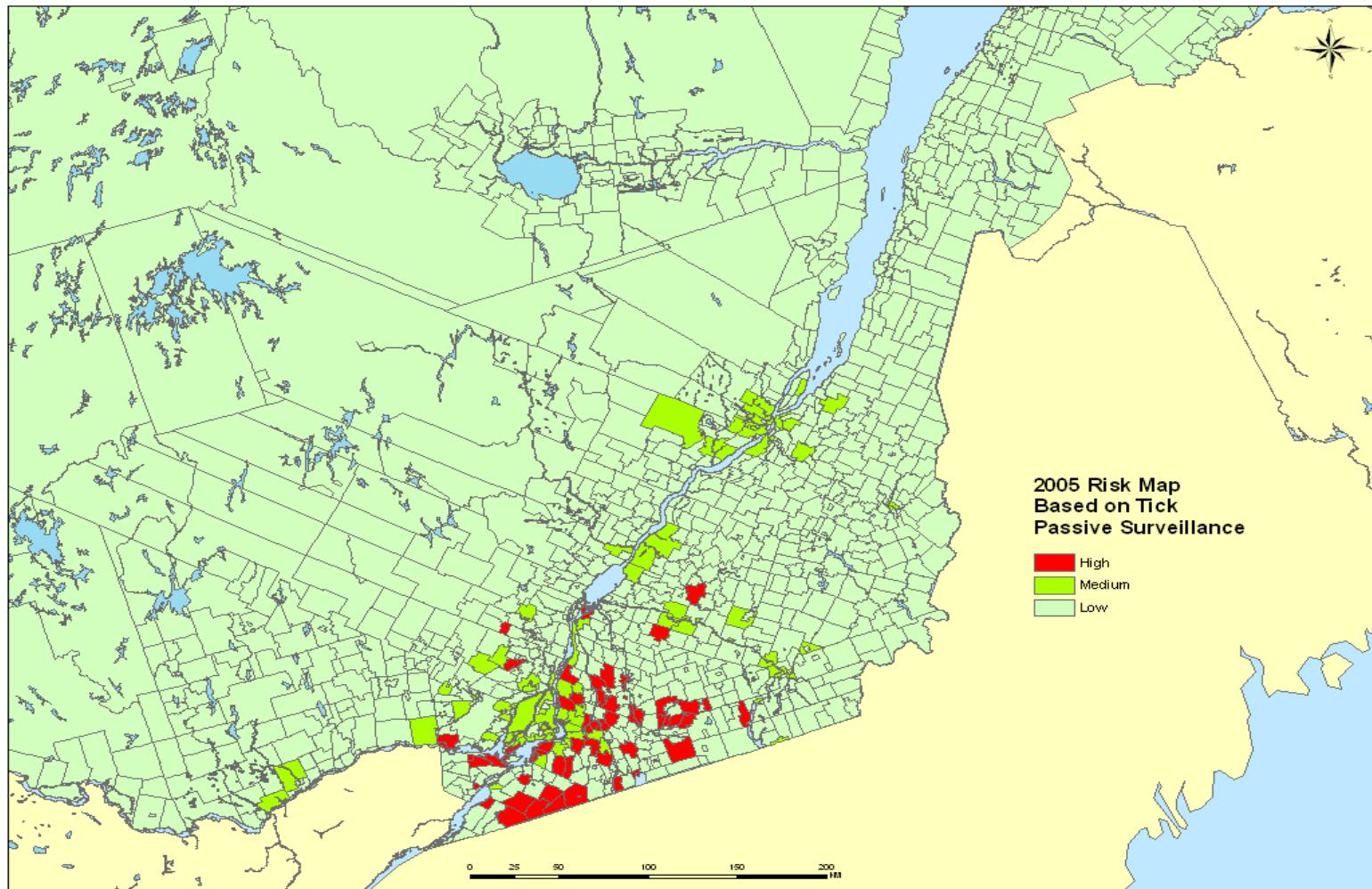
# Spatial occurrence of Lyme disease risk - Provincial scale



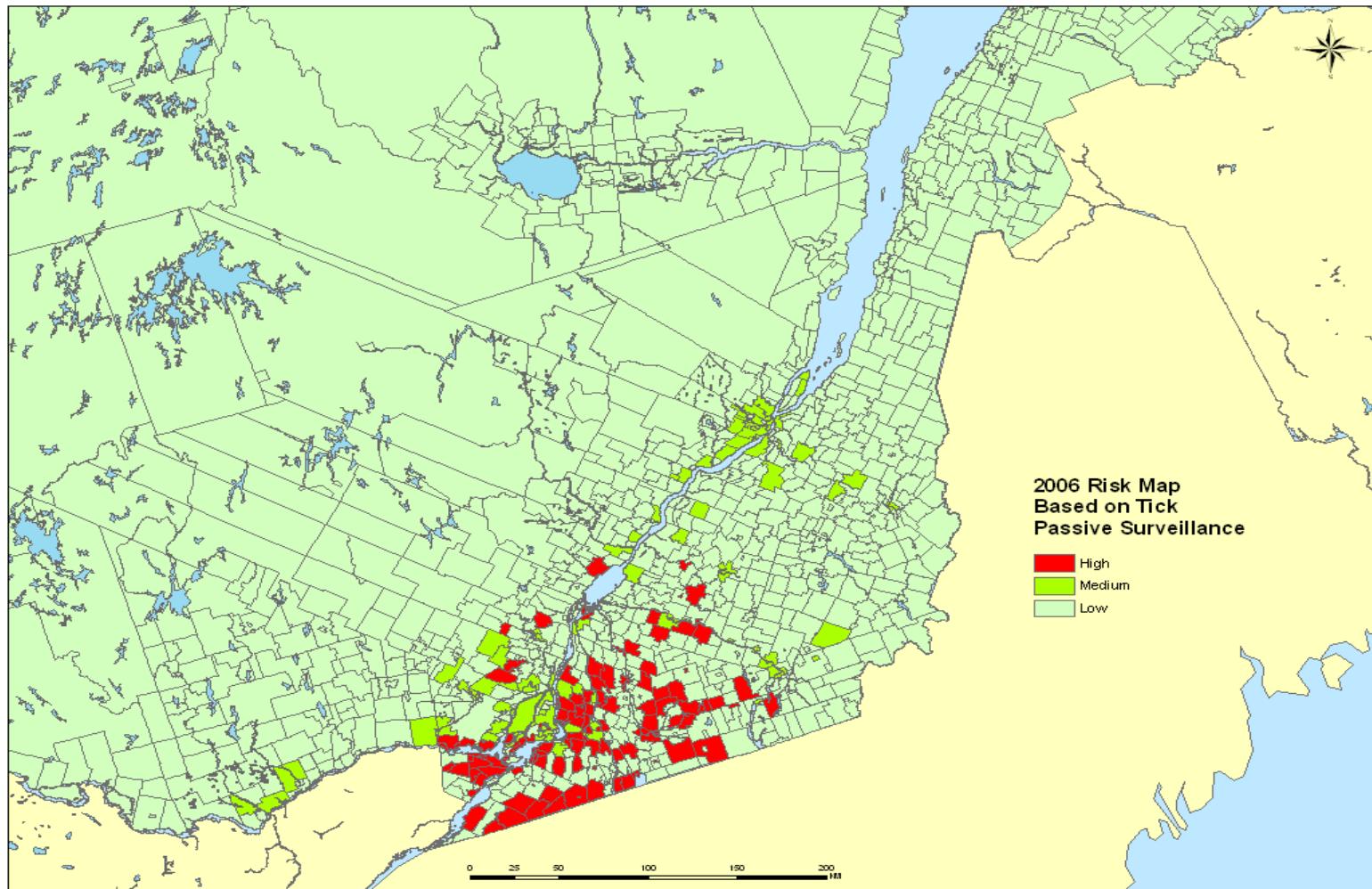
Risk Level os sites	Number of sites	Number of sites with presence of ticks (%)	Number of sites with presence of <i>B.burgdorferi</i> (%)
High risk	48	29(60.4)	4 (13,8)
Moderate risk	30	4 (13.3)	0(0)
Total	78	33 (42.3)	4 (12,1)

Koffi et al., 2012 J Med Entomol

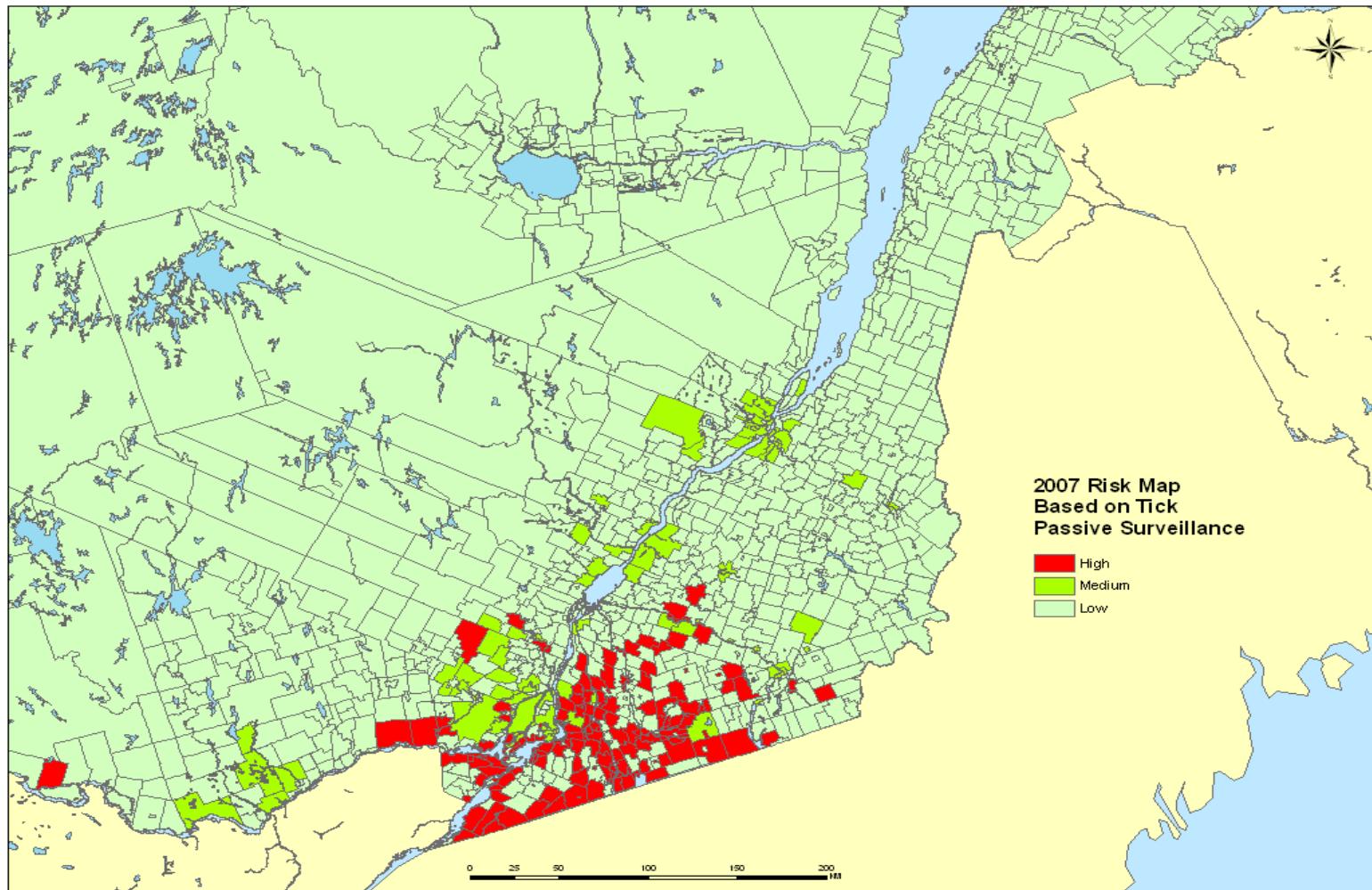
# Alert Map Québec 2005



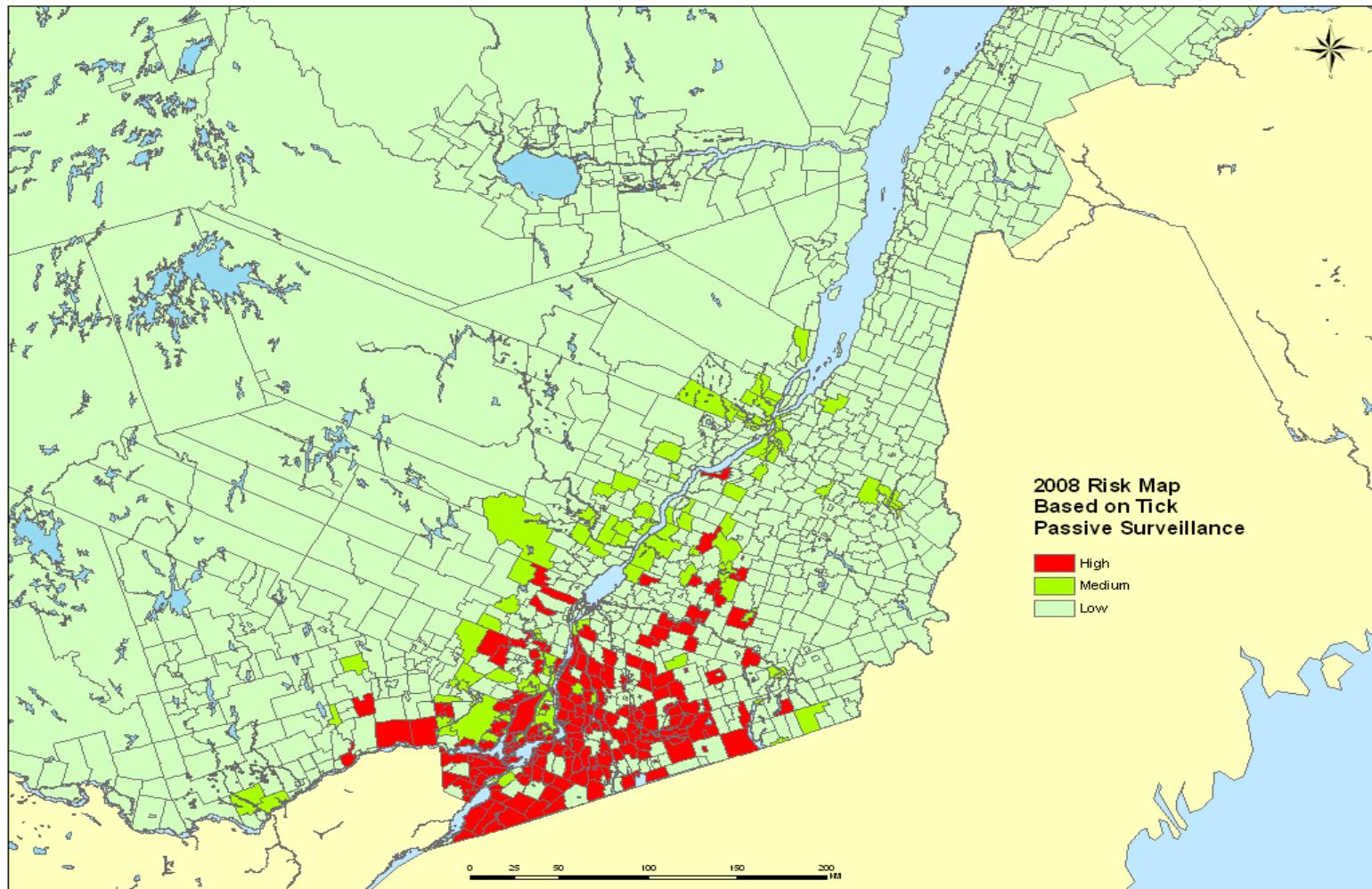
# Alert Map Québec 2006



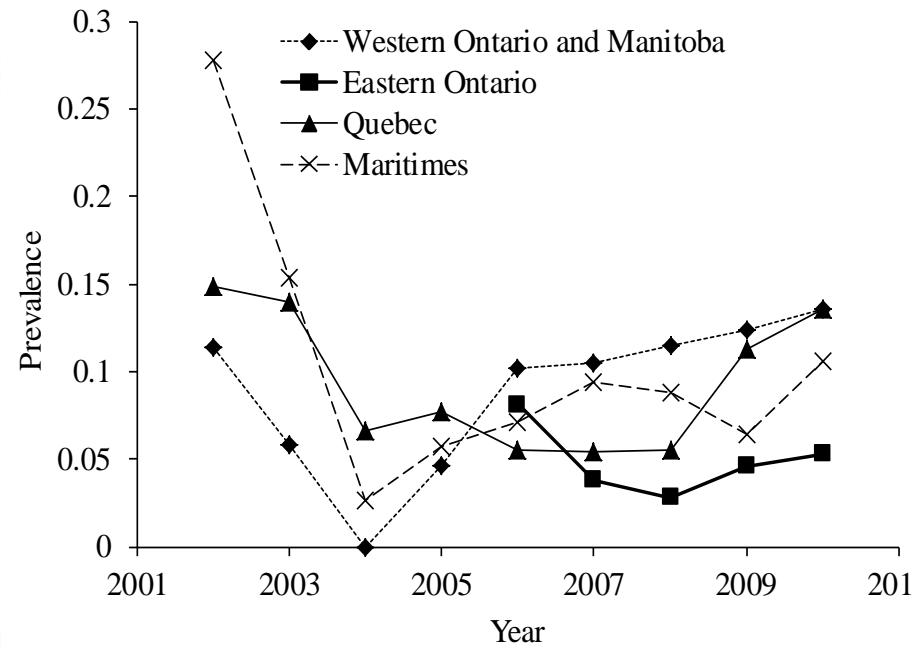
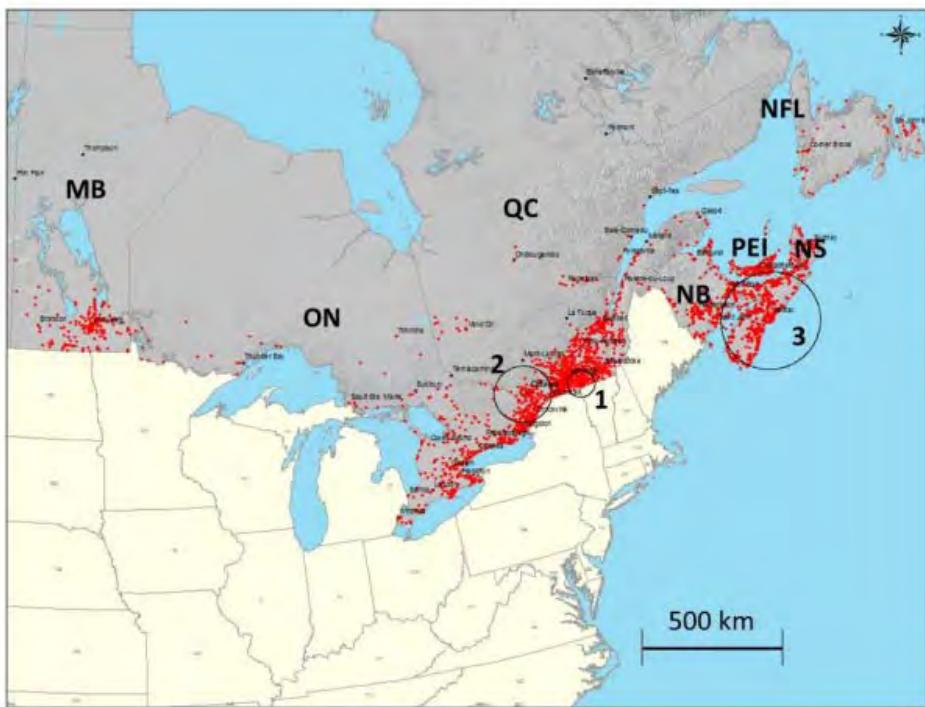
# Alert Map Québec 2007



# Alert Map Québec 2008



# Are Alert maps timely?

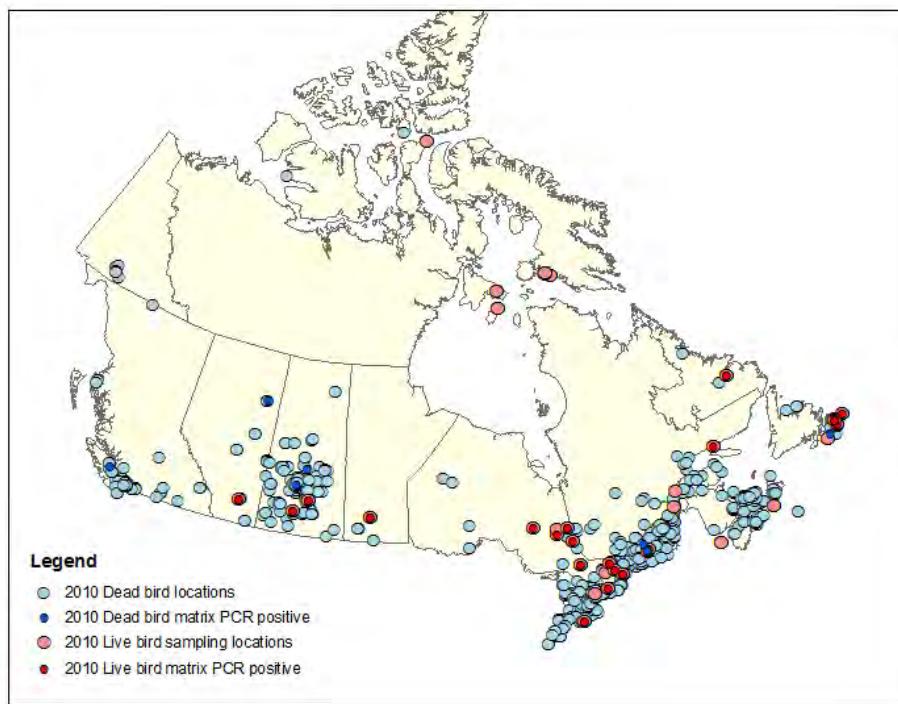


Detection of new tick populations in Alert maps in eastern Canada gives up to 5 years warning of significant Lyme disease risk

Ogden et al., 2013 J Appl Ecol

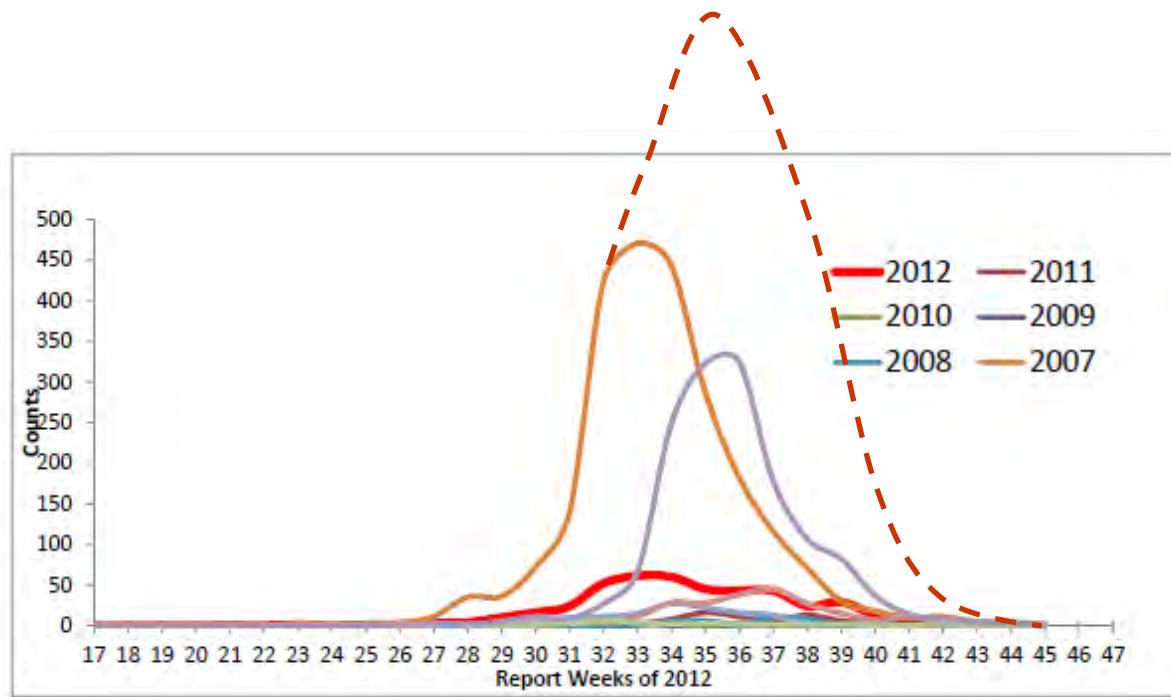
# Highly pathogenic avian influenza surveillance

- Surveillance for HPAI in wild birds via the Interagency Wild Bird Survey (PHAC, CFIA, EC, PT Animal and Public Health) managed by NGO CCWHC



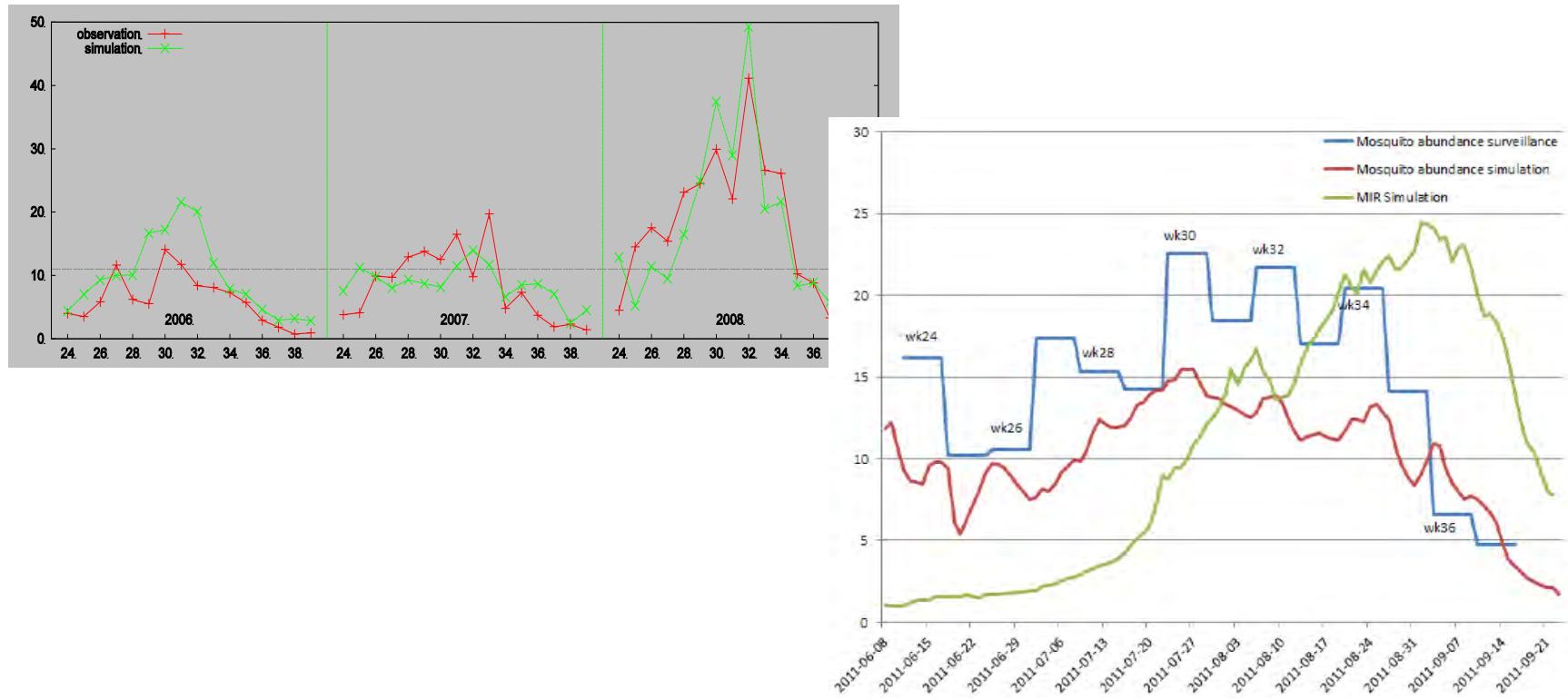
# West Nile Virus surveillance

- Human case surveillance - weekly
- Surveillance for animal sentinels (horses and dead corvids) – initially the main method, now less used
- Mosquito surveillance (most, but not all Provinces) – weekly
- Timeliness allows prompt response



# West Nile risk forecasting

- Using weather and geographic variables to predict mosquito abundance and infection prevalence ( $M \times P = \text{WNv environmental risk}$ )



Wang et al., 2011 J Med Entomol; Zhu et al in prep

# The future: opportunities, challenges and gaps

## Opportunities:

- Demonstration (unsung) that ‘environmental’ surveillance for zoonoses gets us ahead of the epidemic curve
- Global traction on One Health
- Global recognition that pandemic influenza may arise from any animal species

## Challenges:

- A changing world (climate change and other drivers) will increase the rate of emergence of zoonoses globally and in Canada.....
- .....at a time of fiscal constraint

## Gaps:

- Buy-in by public health = knowledge gaps on zoonoses, public health, One Health
- Buy-in by the livestock industry = industry penalised for a health outcome
- Mechanisms for management of animal/environmental health programs for a health outcome = changing mandates and policies at high levels