Public Health Agency of Canada
Agence de santé publique du Canada

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Climate change: Impacts on vector-borne and zoonotic diseases

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Talk plan

1. Climate change
2. Emergence of infectious diseases
3. Climate change and vector-borne disease ecology
4. Climate change and ecology of hosts of vectors/ pathogens
5. Emergence by geographic spread
6. Emergence by spill-over
7. Emergence by evolution
8. Predicting public health risks

Cette présentation a été effectuée le 23 octobre 2006, au cours du symposium "Saurons-nous conjuguer santé et changements climatiques?" dans le cadre des Journées annuelles de santé publique (JASP) 2006. L'ensemble des présentations est disponible sur le site Web des JASP, à l'adresse http://www.inspq.qc.ca/jasp.

Public health and vector-borne/zoonotic diseases

Vector-borne and zoonotic diseases pose an environmental health risk. My job is to:

1. Assess the <u>potential</u> risk
   - What vectors/pathogens exist in the environment?
   - Where do they occur in the environment?
   - When do they occur in the environment?
2. Assess the <u>actual</u> risk
   - What pathogens, where and when are likely to be transmitted (spill-over) to the human population
   - A function of (1) and human behaviour:
     - Occupation
     - Geographic location
     - Leisure activities

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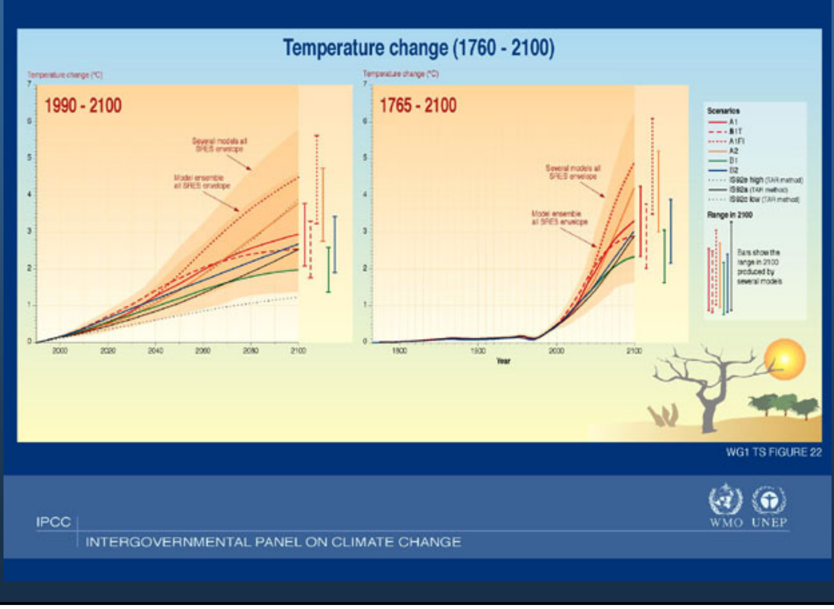
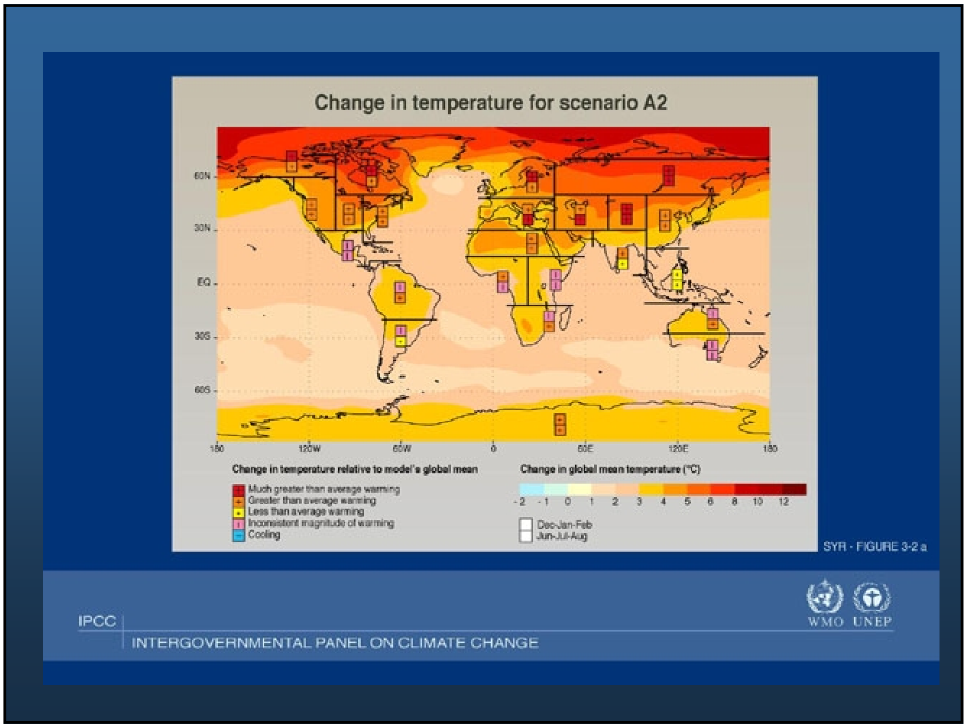
1. Projected temperature change according to different IPCC emission scenarios



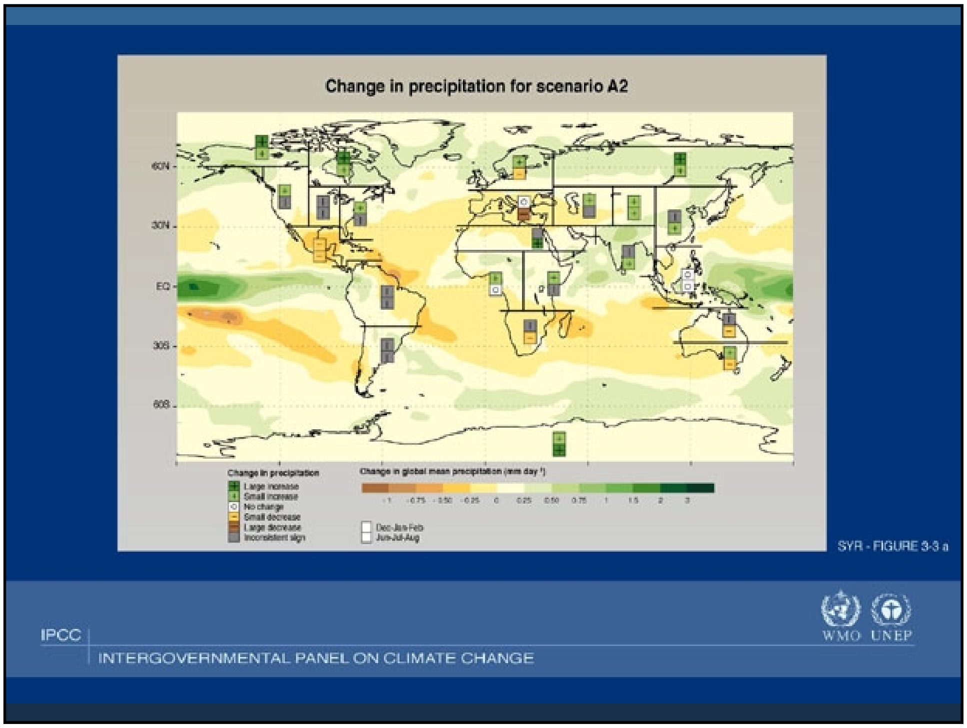


Change in temperature for scenario A2

SYR - FIGURE 3-2 a

IPCC

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

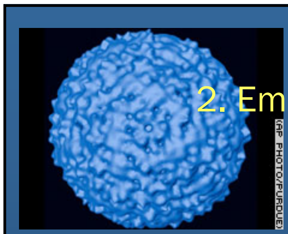


Change in precipitation for scenario A2

SYR - FIGURE 3-3 a

IPCC

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE



2. Emergence/re-emergence of infectious diseases

1. Human awareness (Lyme, SARS)
2. Introduction of exotic parasites into existing suitable host/vector/human-contact ecosystem (West Nile, SARS)
3. Geographic spread from neighbouring endemic areas (Lyme, Rabies)
4. Ecological change causing endemic disease of wildlife to ‘spill-over’ into humans (Lyme, Hantavirus, Nipah)
5. True ‘emergence’: evolution and fixation of new, pathogenic genetic variants of previously more benign parasites/microparasites (HPAI)

3. How can climate affect vector-borne disease ecology?

Affecting geographic distribution of vectors

- Vector survival $^{T,RHP(mossies)}$
- Vector activity (biting rate) ^{T,RHP}
- Host species range and density ^{T,RHP} (ticks)
- Habitat distribution ^{T,RHP}

Affecting existence of, and force of infection in, endemic transmission cycles

- Vector abundance ^{T,RHP}
- Vector seasonality ^{T,RHP}
- Extrinsic incubation period (latent period in mossie, duration of dvlpt in tick) ^{T}
- Host species abundance & demography^{T,RHP}

General VBD

$$R_0 = \frac{Na^2 \beta_{V-I} \beta_{I-V} p^n}{H(r+h)(-\ln p)}$$

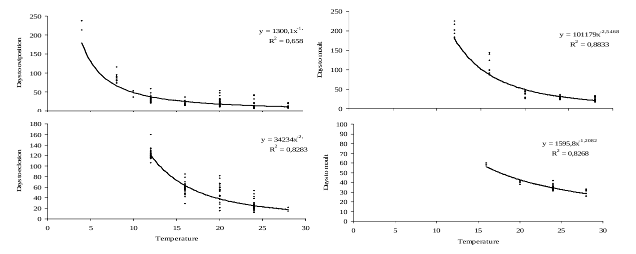
TBD (Randolph Parasitol Today 1998)

$$R_0 = \frac{Nf \beta_{V-T} \beta_{T-T} \beta_{T-V} p^n F}{H(r+h)}$$

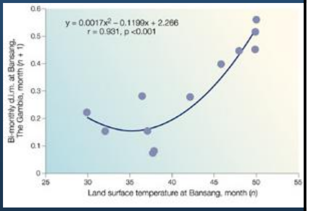
Vector Survival

- Direct effects of temperature on mortality rates*
- Temperature effects on development: at low temperatures lifecycle lengthens & mortality outstrips fecundity*
- Lower humidity increases the energy requirement for host seeking by ticks shortening their lives*
- Lower rainfall reduces breeding areas for mosquitoes, compounded by density-dependent intraspecific competition amongst larvae
- More complex community-associated changes (habitat structure, predator abundance etc)

* Non-linear (quadratic) relationships with temperature



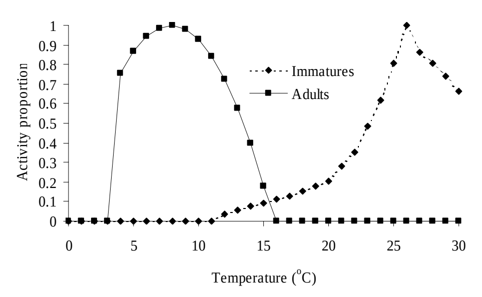
I. scapularis development: Ogden et al. J. Med. Entomol. 2004



Tsetse mortality: Randolph & Rogers Nature Rev Micro 2003

Vector Activity

- Arthropods are poikilotherms: increased temperature increases activity, but very high temperatures decrease activity
- Increased RH increases activity, heavy rainfall decreases activity
- Increased activity increases transmission rates and reduces mortality rate per transmission event (but not linearly – increased per day per capita mortality)

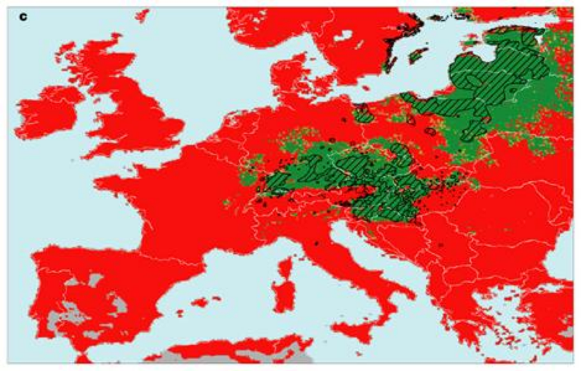


Ogden et al. Int. J. Parasitol. 2005 Vail & Smith J. Med. Entomol. 1998

Vector and Host Seasonality

- Vector-borne zoonoses are mostly maintained by wildlife: humans are irrelevant to their ecology
- Vectors and their hosts are subject to seasonal variations in abundance and demographic processes
- Vector seasonality due to temperature effects on development and activity
- Host demographic processes (reproduction, birth and mortality rates), affected directly by weather and indirectly by resource availability
- Phenomena associated with climate-independent day-length also affect seasonality

Climate change alters the geographic footprint of VBD



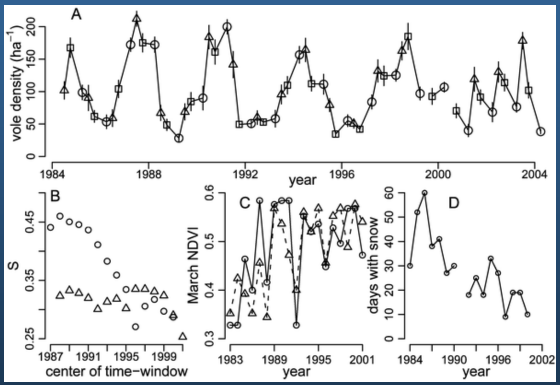
e.g. Tick-borne encephalitis virus in Europe: Randolph & Rogers Proc R Soc Lond 2000

4. Climate change and host ecology

Climate influences:

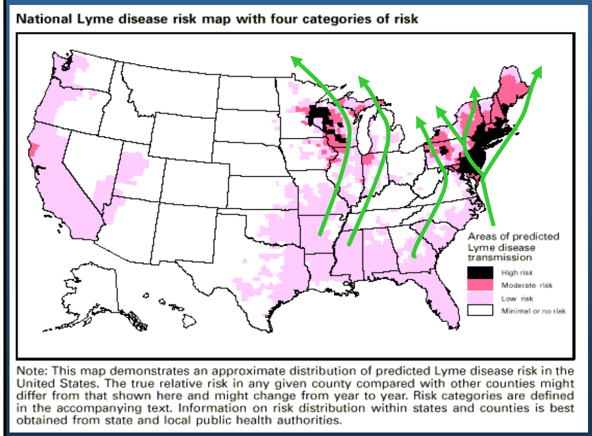
1. Natural host abundance and
2. Dynamics of pathogen transmission cycles by affecting:
   - Reproduction rates (↑ by shorter winters, increased rainfall)
   - Mortality rates (↓ by shorter winters, increased rainfall)
   - Seasonal variations (↓ by shorter winters)
   - Inter-annual cycles (↓ by shorter winters, ↑ by increased rainfall - ENSO)
3. Rates of dispersion and migration

Rodent hosts and climate



Bierman et al. Am. Nat. 2006

2% of migratory passerines (birds) carry the Lyme vector *I. scapularis* into, and through, Canada


National Lyme disease risk map with four categories of risk

Note: This map demonstrates an approximate distribution of predicted Lyme disease risk in the United States. The true relative risk in any given county compared with other counties might differ from that shown here and might change from year to year. Risk categories are defined in the accompanying text. Information on risk distribution within states and counties is best obtained from state and local public health authorities.

Northern-migrating ground-feeding birds stop-over in tick-infested habitat

Spring migration coincides with spring activity period of *Ixodes scapularis* nymphs

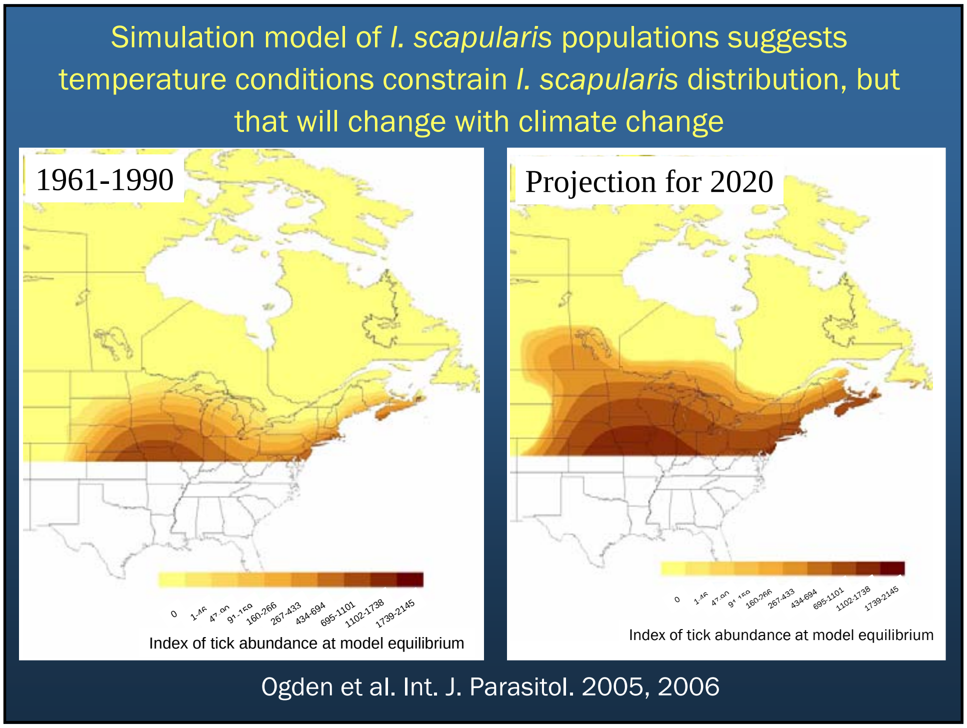
Nymphs feed continuously on birds for 5 days, then drop off into the habitat

Climate change increases range of tick dispersion: 4.5% increase in migration/day per 1C increase in temp: Marra et al Oecologia 2006

5. Emergence by range expansion

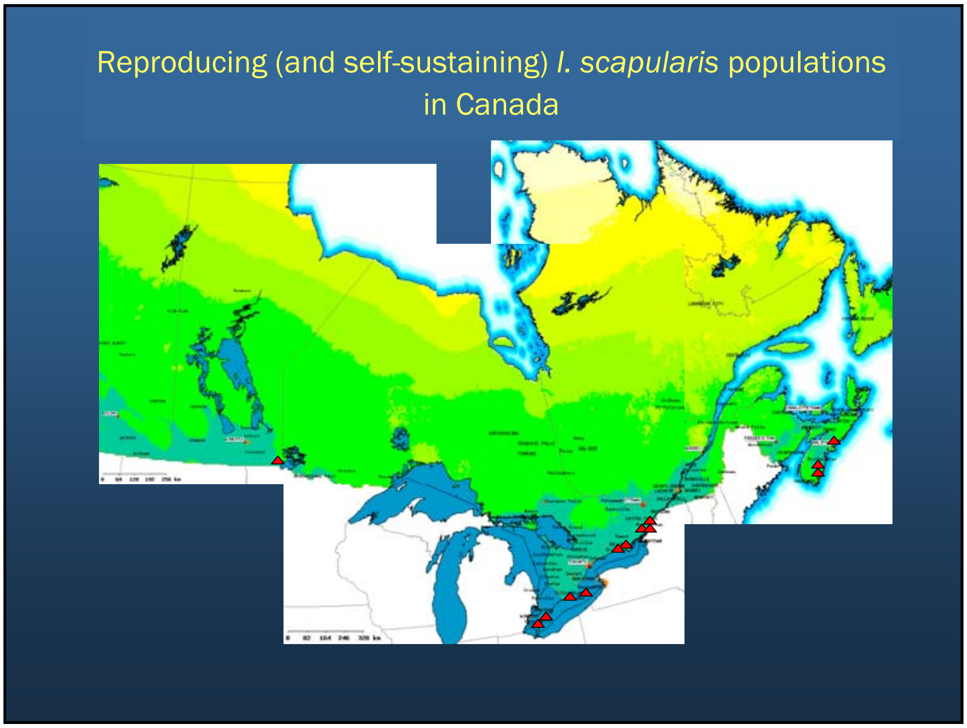
E.g. Lyme disease in Canada:

- Existing suitable ecosystem (hosts/habitat) for tick and pathogen
- Vector already efficiently spread by migrating birds
- Increasing temperature with climate change increases survival of tick vectors carried by birds and establishment of resident populations
- Climate change increases <u>potential</u> risk



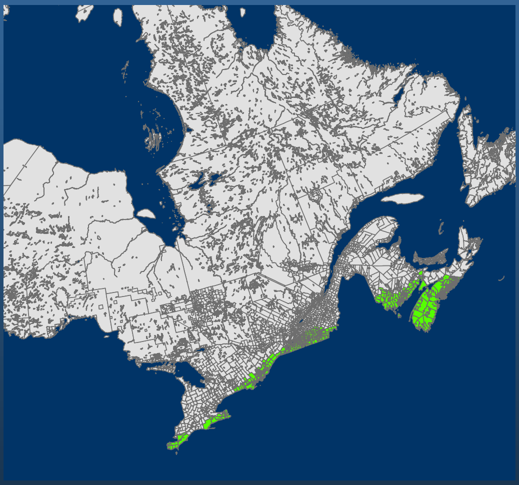
Simulation model of *I. scapularis* populations suggests temperature conditions constrain *I. scapularis* distribution, but that will change with climate change

Ogden et al. Int. J. Parasitol. 2005, 2006



Reproducing (and self-sustaining) *I. scapularis* populations in Canada

Possible populations by 2020



Cut off value of algorithm for population establishment determined by maximum Youden index: Sensitivity = 93.7% Specificity = 94.7%

5. Emergence by spill-over

E.g. Leptospirosis and Hantavirus

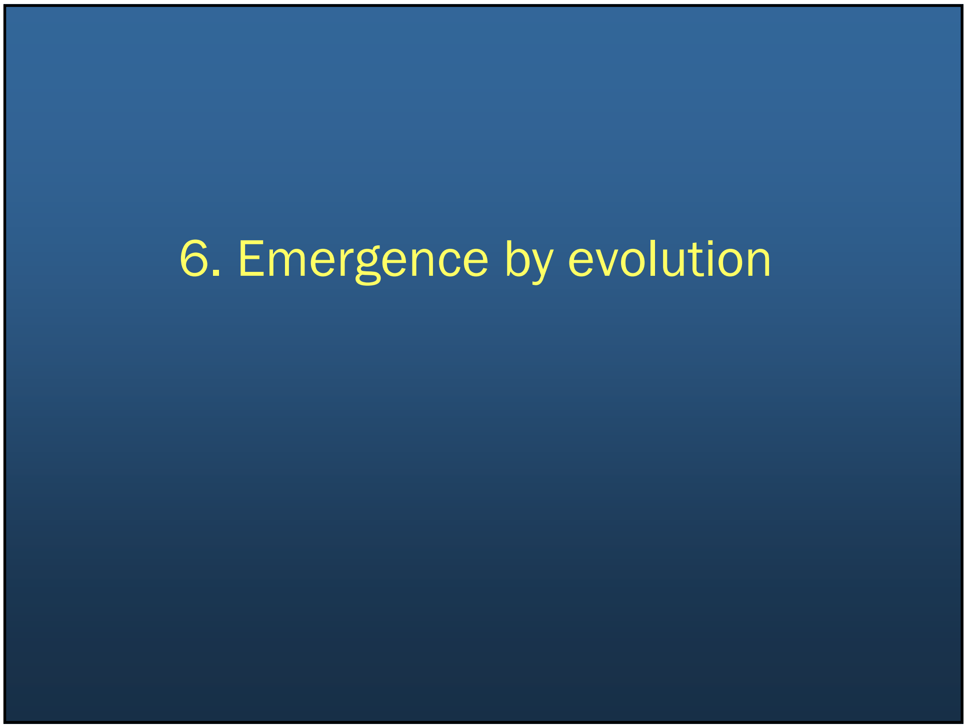
- Endemic pathogens of rodents in North America (and globally)
- Increased temp & rainfall increases rodent density (↑ food supply)

Climate change increases <u>potential</u> risk

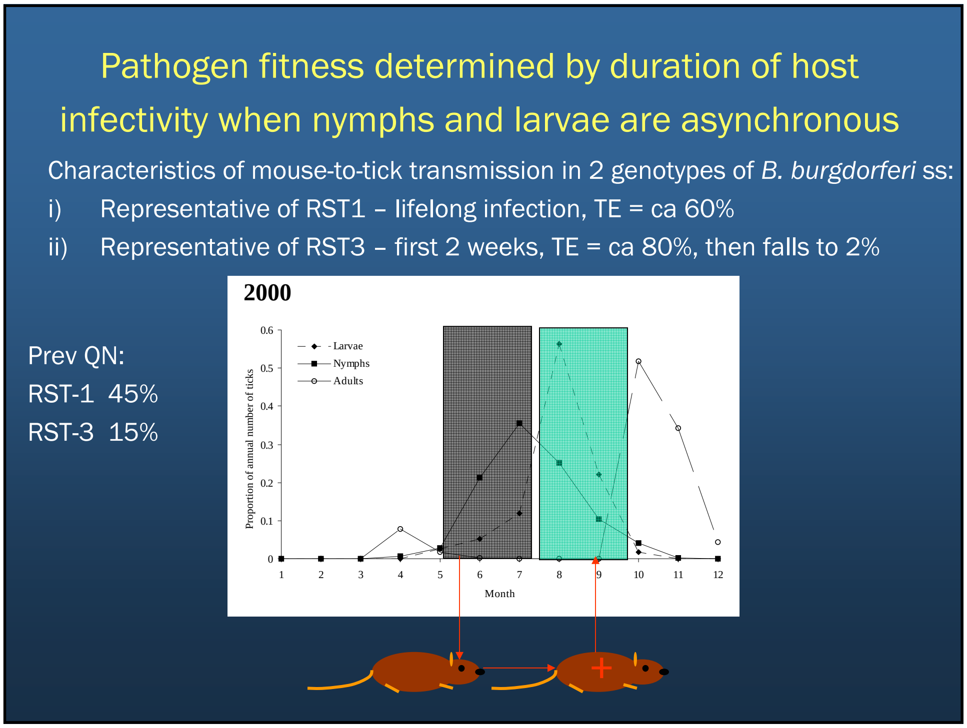
- Heavy rainfall events increase direct human contact with rodents and rodent faeces/urine
- Heavy rainfall events increase human contact with urine-contaminated water

Climate change increases <u>actual</u> risk

Hjelle & Glass JID 2000; Bharti et al. Lancet 2003



6. Emergence by evolution



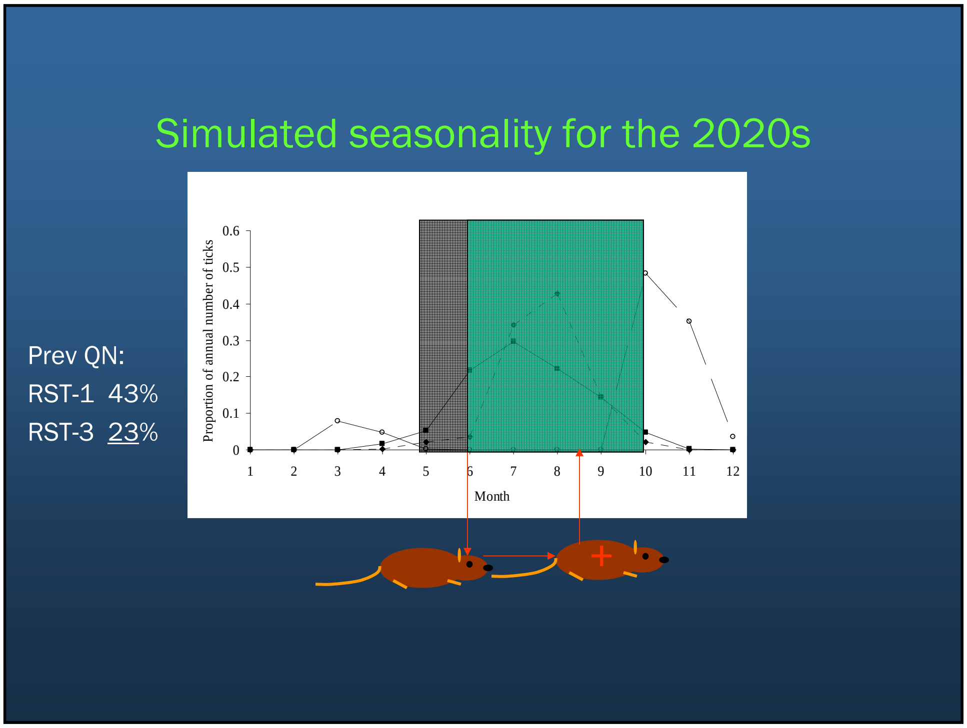
Pathogen fitness determined by duration of host infectivity when nymphs and larvae are asynchronous

Characteristics of mouse-to-tick transmission in 2 genotypes of *B. burgdorferi* ss:

i) Representative of RST1 – lifelong infection, TE = ca 60%

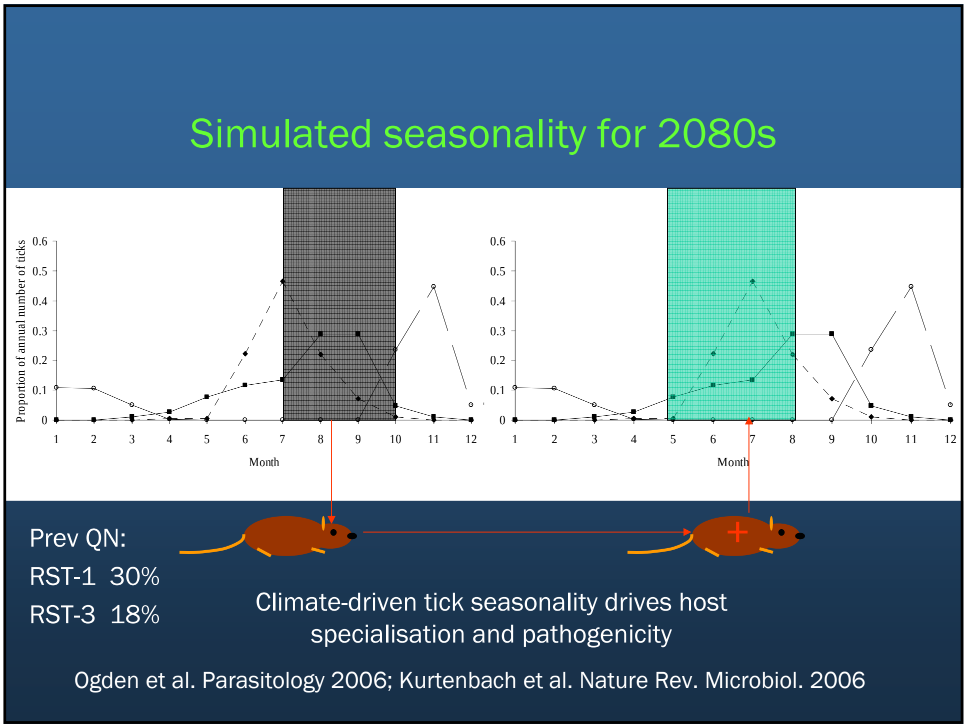
ii) Representative of RST3 – first 2 weeks, TE = ca 80%, then falls to 2%

Prev QN:
RST-1 45%
RST-3 15%



Simulated seasonality for the 2020s

Prev QN:
RST-1 43%
RST-3 23%

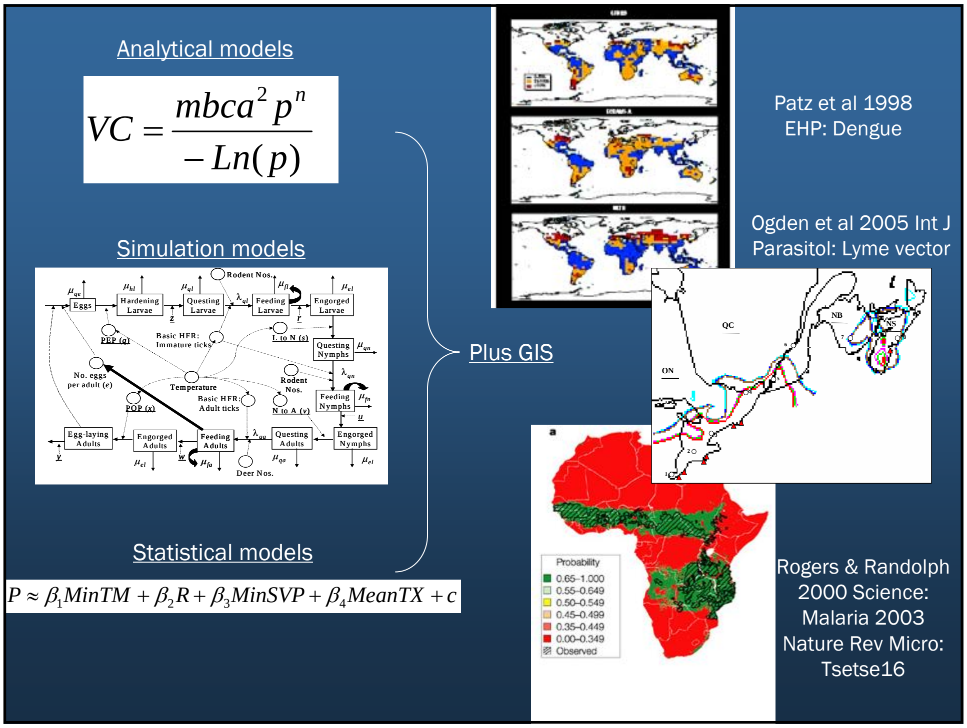


Simulated seasonality for 2080s

Prev QN:
RST-1 30%
RST-3 18%

Climate-driven tick seasonality drives host specialisation and pathogenicity

Ogden et al. Parasitology 2006; Kurtenbach et al. Nature Rev. Microbiol. 2006



Analytical models

$$VC = \frac{mbca^2 p^n}{-Ln(p)}$$

Simulation models

Plus GIS

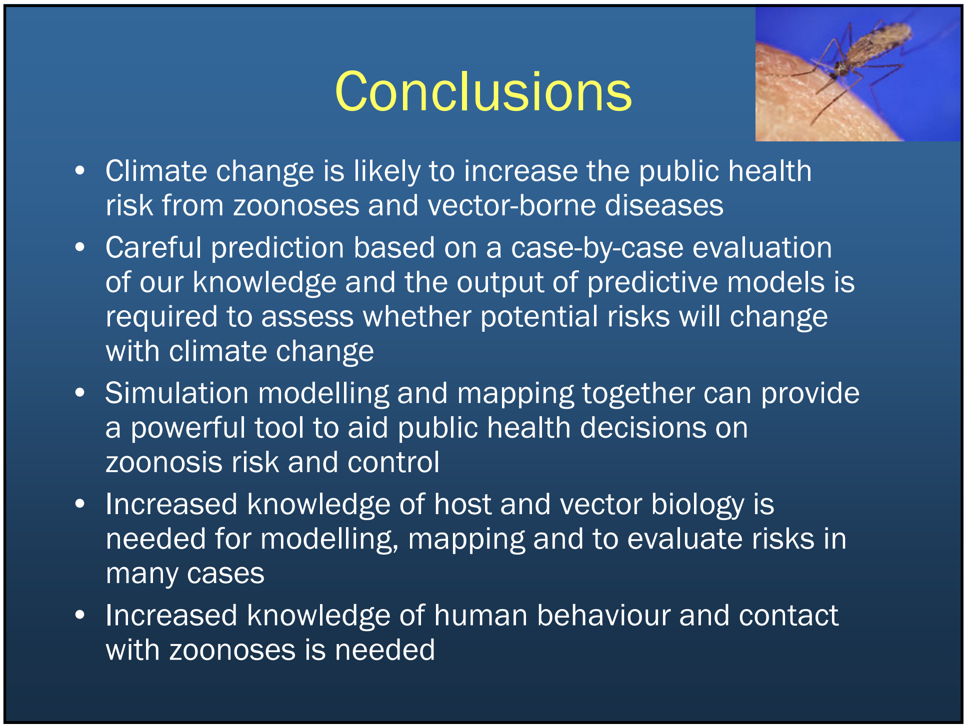
Statistical models

$$P \approx \beta_1 MinTM + \beta_2 R + \beta_3 MinSVP + \beta_4 MeanTX + c$$

Patz et al 1998
EHP: Dengue

Ogden et al 2005 Int J
Parasitol: Lyme vector

Rogers & Randolph
2000 Science:
Malaria 2003
Nature Rev Micro:
Tsetse16



Conclusions

- Climate change is likely to increase the public health risk from zoonoses and vector-borne diseases
- Careful prediction based on a case-by-case evaluation of our knowledge and the output of predictive models is required to assess whether potential risks will change with climate change
- Simulation modelling and mapping together can provide a powerful tool to aid public health decisions on zoonosis risk and control
- Increased knowledge of host and vector biology is needed for modelling, mapping and to evaluate risks in many cases
- Increased knowledge of human behaviour and contact with zoonoses is needed