# EFFECTS OF CLIMATE CHANGE ON WILDLIFE HEALTH:
## Implications for Conservation, Domestic Animals, and Human Health

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**Global Health Programs**
**Wildlife Conservation Society**

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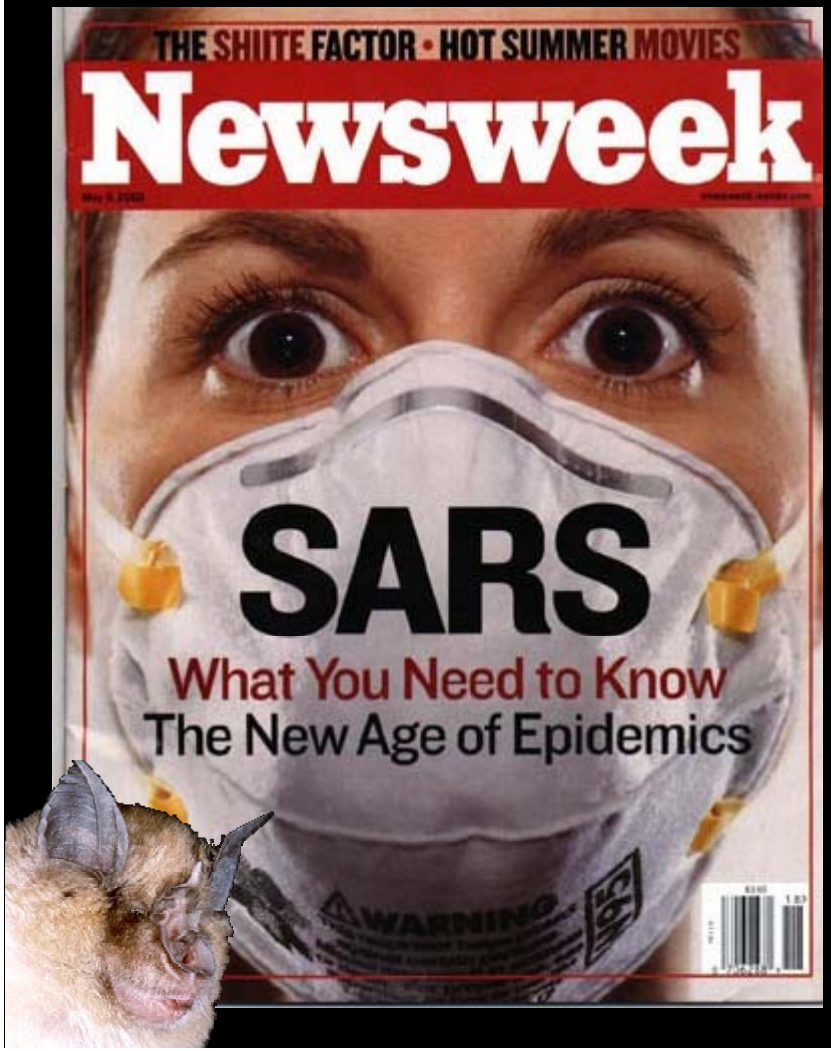
***Wildlife health…***

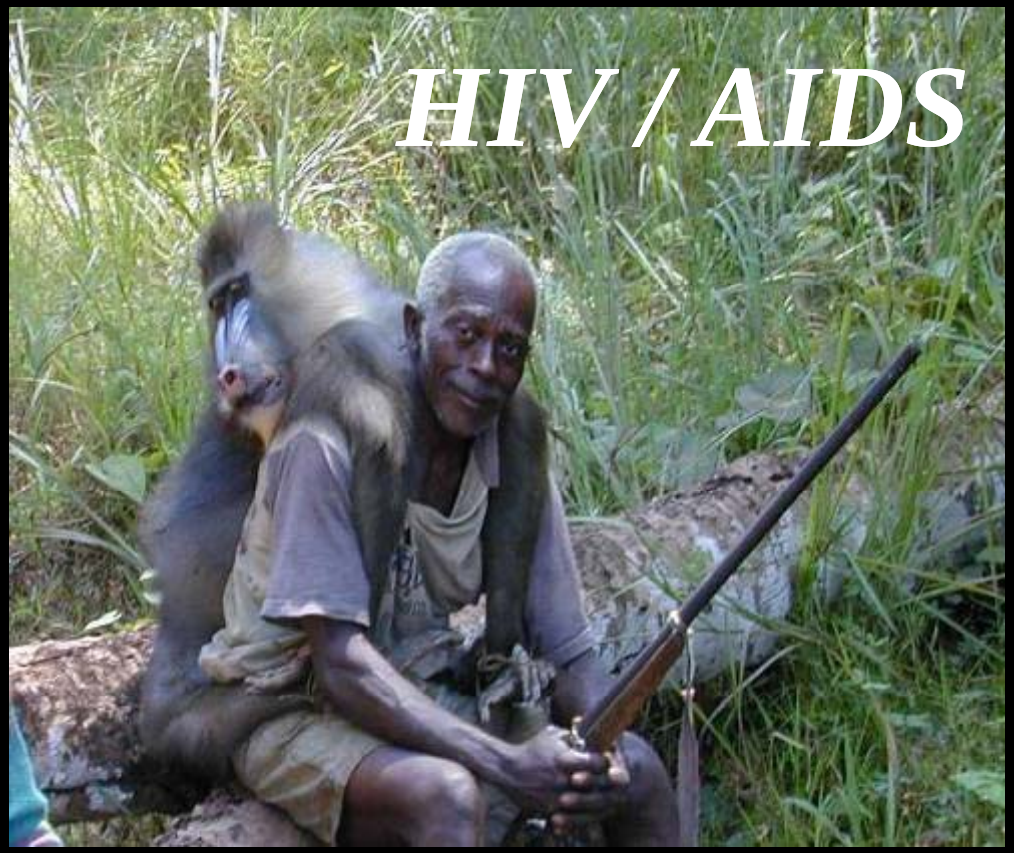
***a very important issue.***

# *Public health concern*

- Most EID are zoonoses
- 72% of these have a wildlife origin

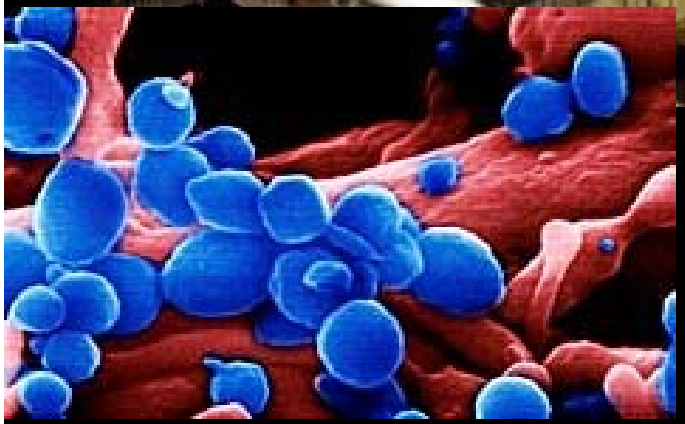
(Jones et al, 2008. Nature)



# *A concern for agriculture*

Avian Influenza



Bovine TB

# *Conservation concern*

- Anthropogenic disease

- Pollution
- Foreign pathogens
- Environmental stress

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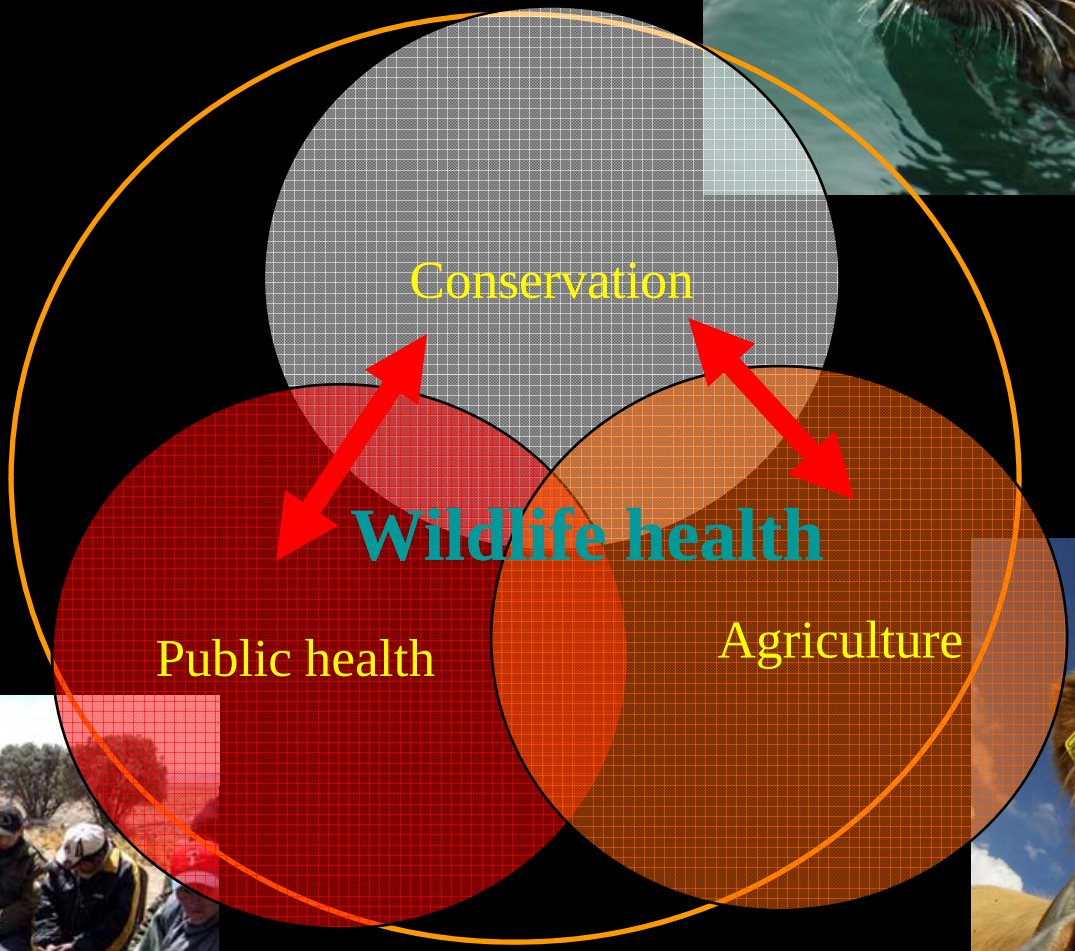
# *Everyone's concern?*



# *Are biodiversity and health linked?*

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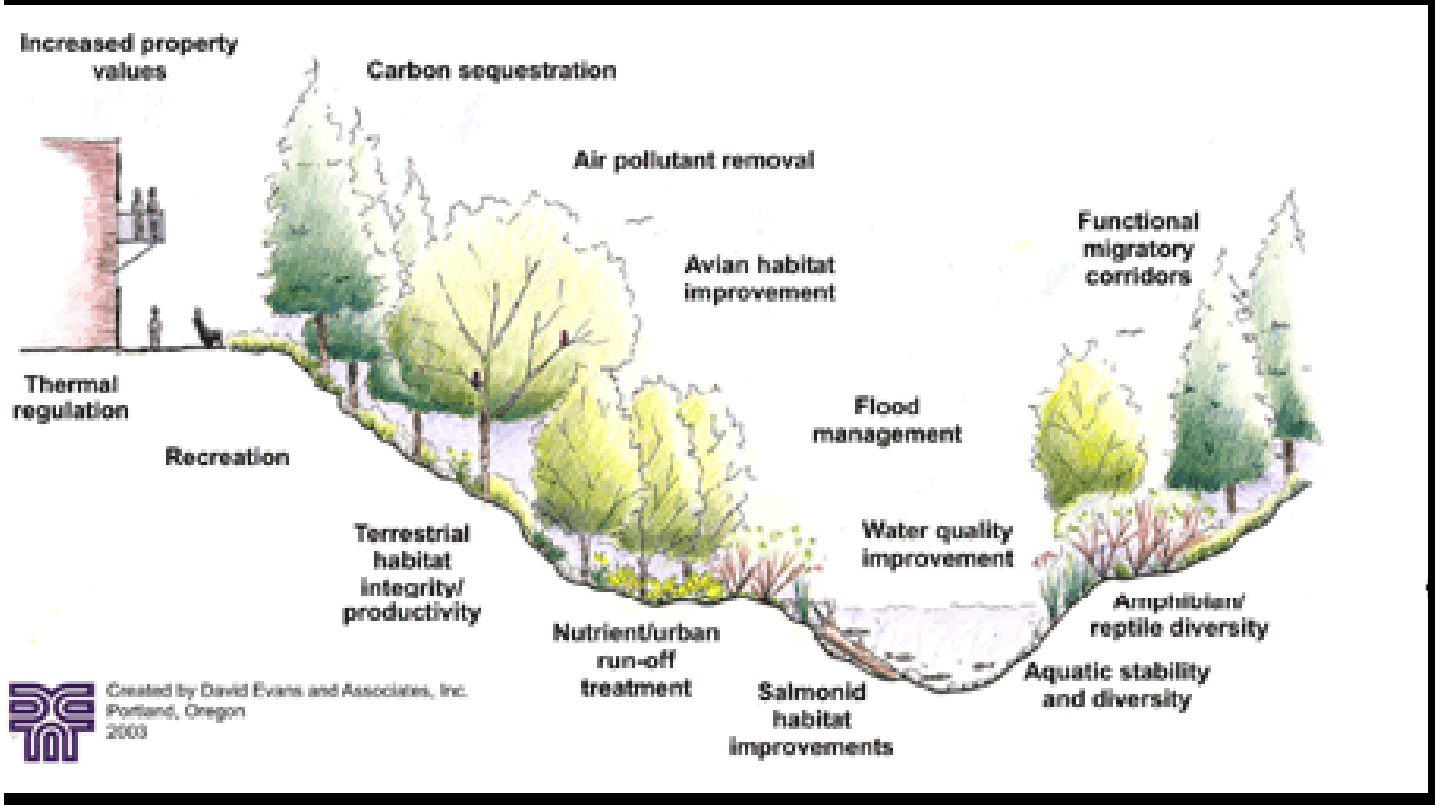
# ECOSYSTEM SERVICES

**BIODIVERSITY** → **FUNCTIONING ECOSYSTEM** → **HEALTH**



***The concept of health,***
***in the wild…***

# THE CONCEPT OF HEALTH

## Why should it be different in the wild?

ABSENCE OF SANITATION:

1. No preventative medicine schemes (e.g. vaccines)
2. No treatments (antibiotics, surgery, etc.)
3. No chemical hygiene (soap, detergent, desinfection, etc)

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# THE CONCEPT OF HEALTH

CONSEQUENCES:

1. Life in pathogen-rich environments

2. Immunological training and experience

3. Natural selection of the infection resistant

= Populations with greater intrinsic resistance to infections, but vulnerable when this resistance is jeopardized

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# NATURAL DISEASE

Endemic viruses, bacteriae, fungi, protozoans and metazoans
(parasite community)

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# NATURAL DISEASE

PATHOGENS ARE PART OF THE ECOLOGICAL COMMUNITY AND PLAY IN IT A SPECIFIC ROLE

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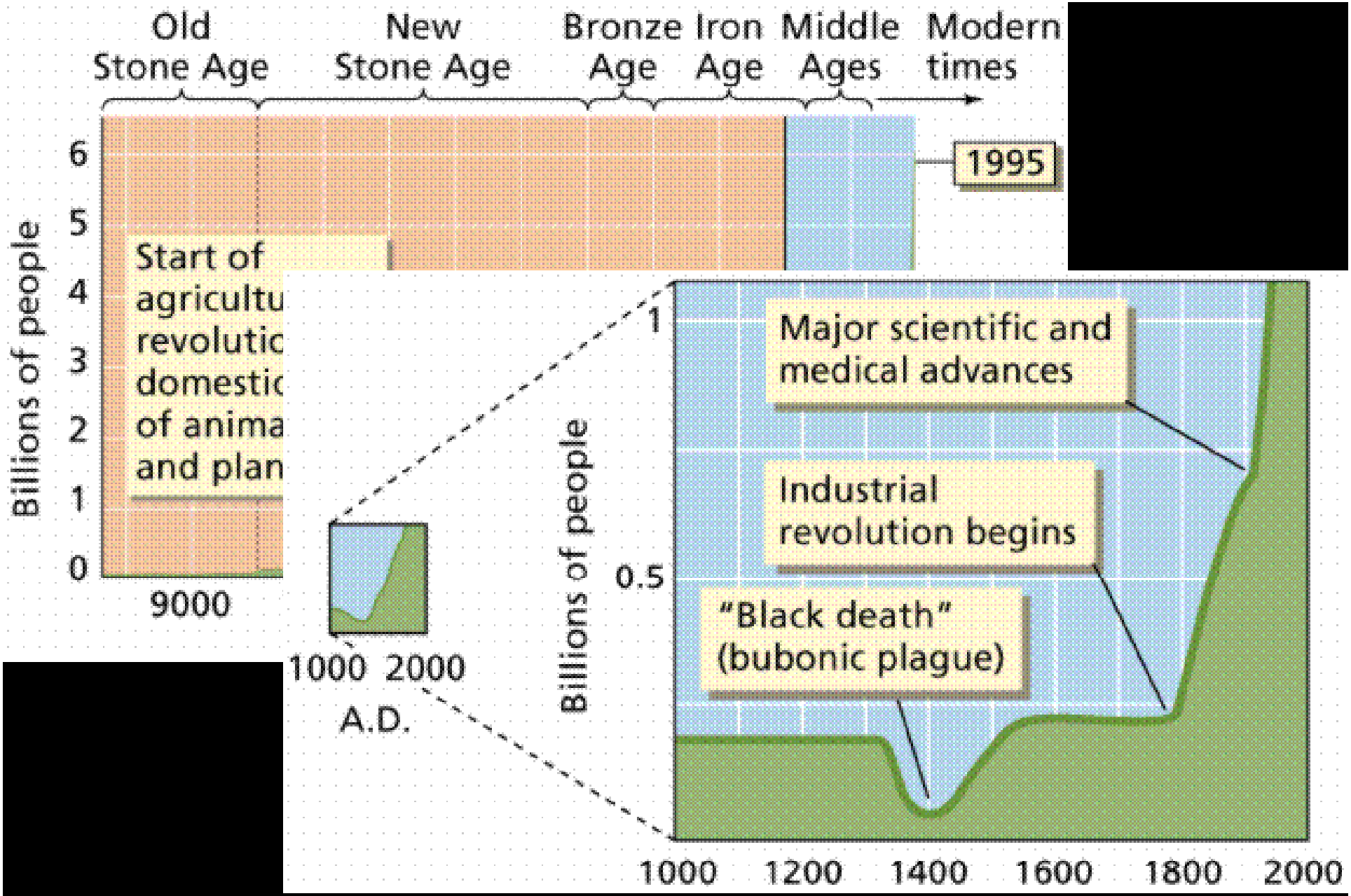
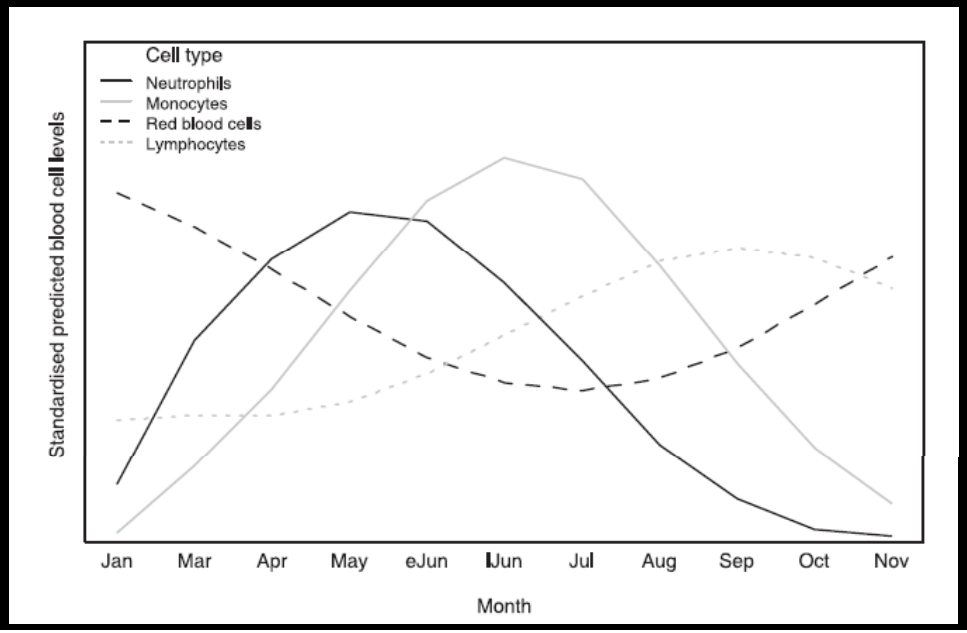
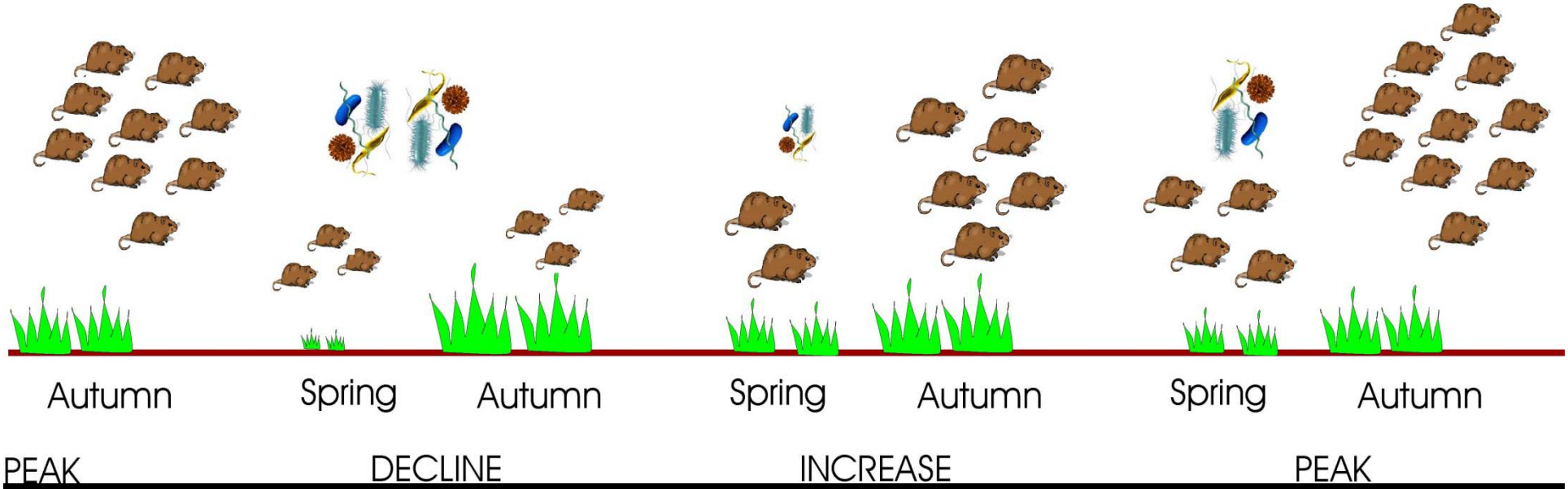



(Figures: Purves et al. Life: The Science of Biology)

# DYNAMICS OF HEALTH

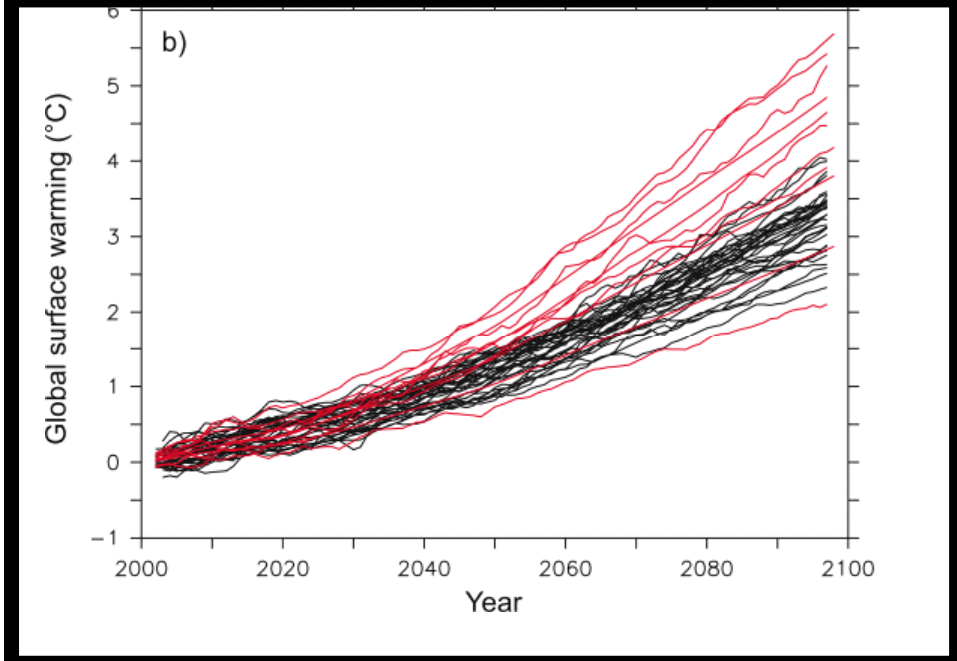


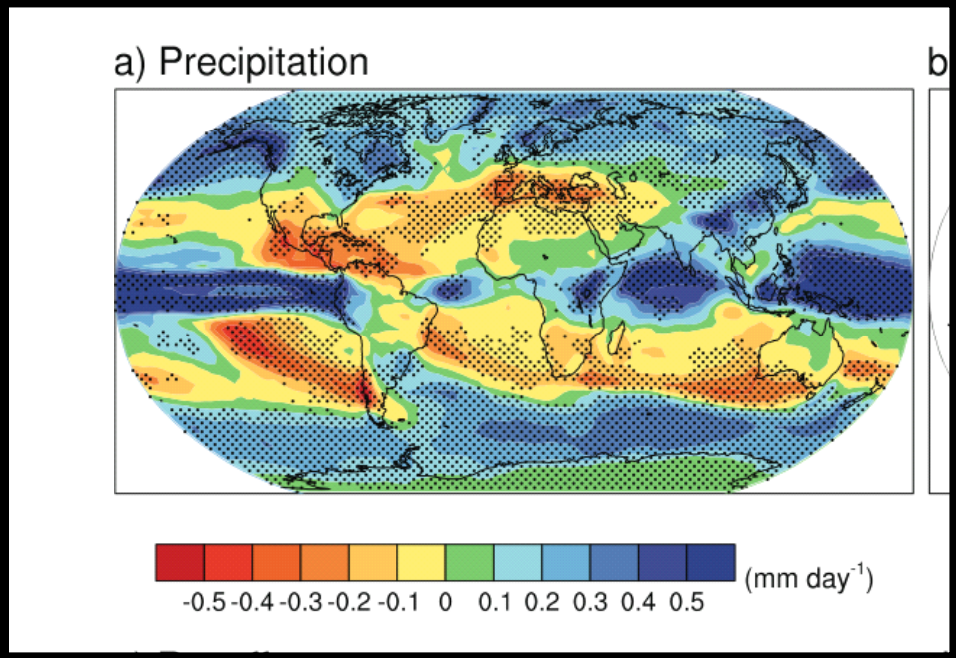




(Beldomenico et al, 2008. J An Ecol)

# *Climate change: mechanisms affecting wildlife health*

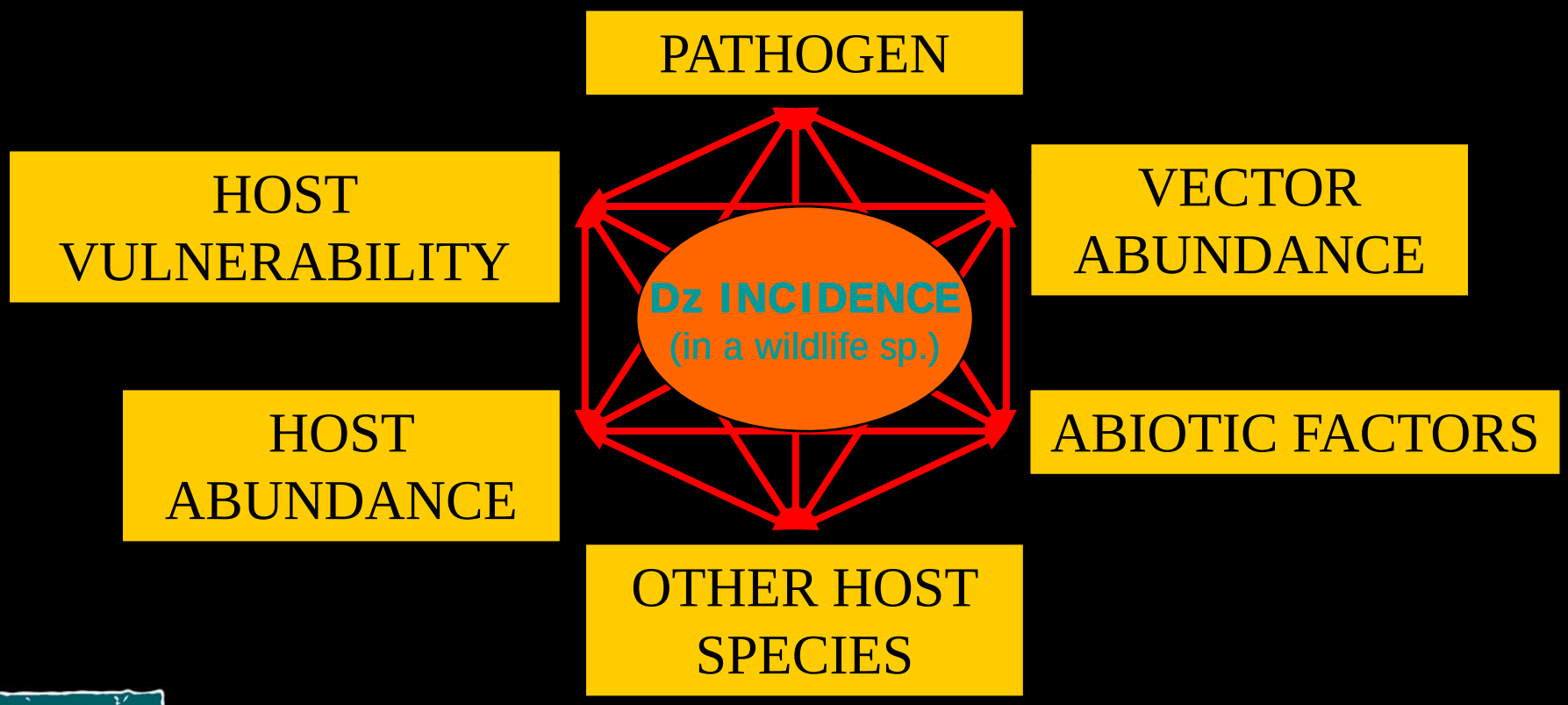
# Climate change



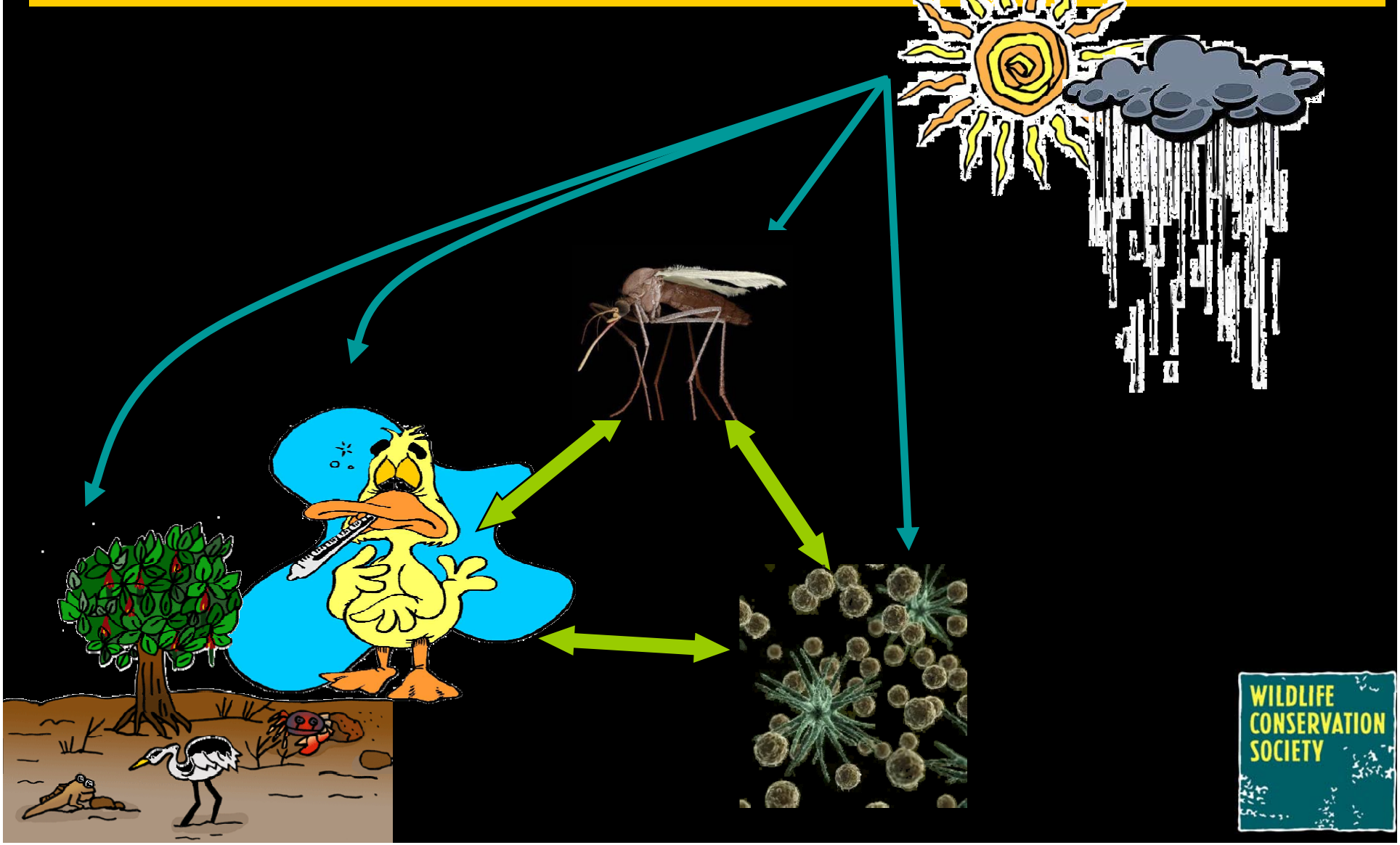

(From the Intergovernmental Panel for Climate Change, 2001)

# In which ways could climate change affect wildlife health?



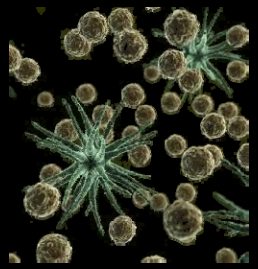

(Simplified web of causation)

# In which ways could climate change affect wildlife health?



# Direct mechanisms

a. Increased pathogen/vector proliferation and/or subsistence



b. Increased host susceptibility to infection

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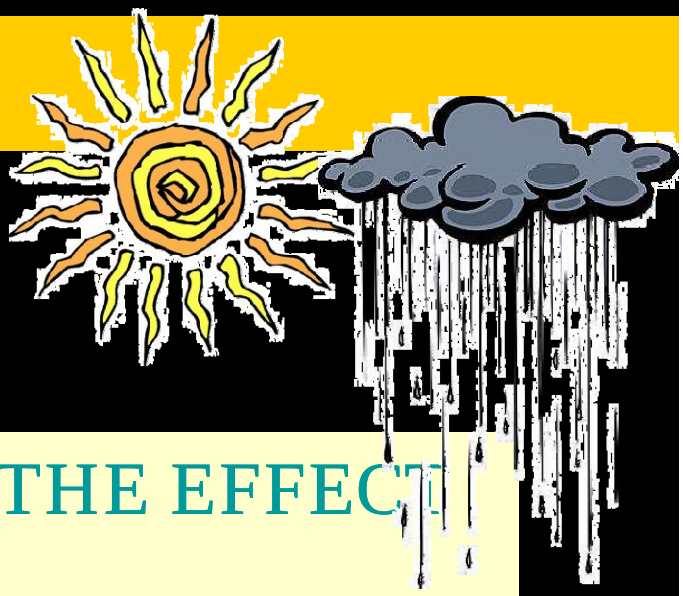
# Measuring the effect



IT IS DIFFICULT TO MEASURE THE EFFECT OF CLIMATE CHANGE:

1. There is need of long term data

2. There are concomitant changes (e.g. pollution, land use, habitat destruction)

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# a. Increased pathogen/vector proliferation and/or subsistence: expanded geographic range

## Vectors

- Malaria
- African trypanosomiasis
- Lyme disease
- Tick-borne encephalitis
- Yellow fever
- Plague
- Dengue
- African horse sickness
- Bluetongue virus

From Harvell et al. 2002. Science

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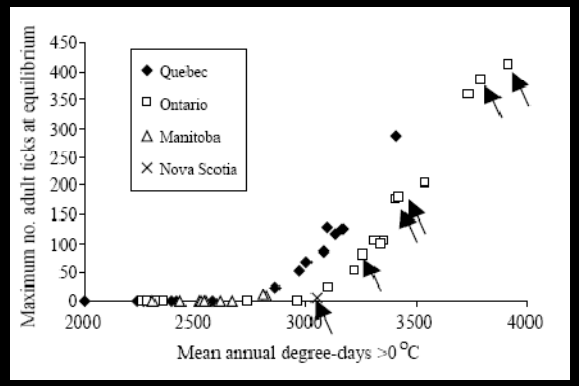
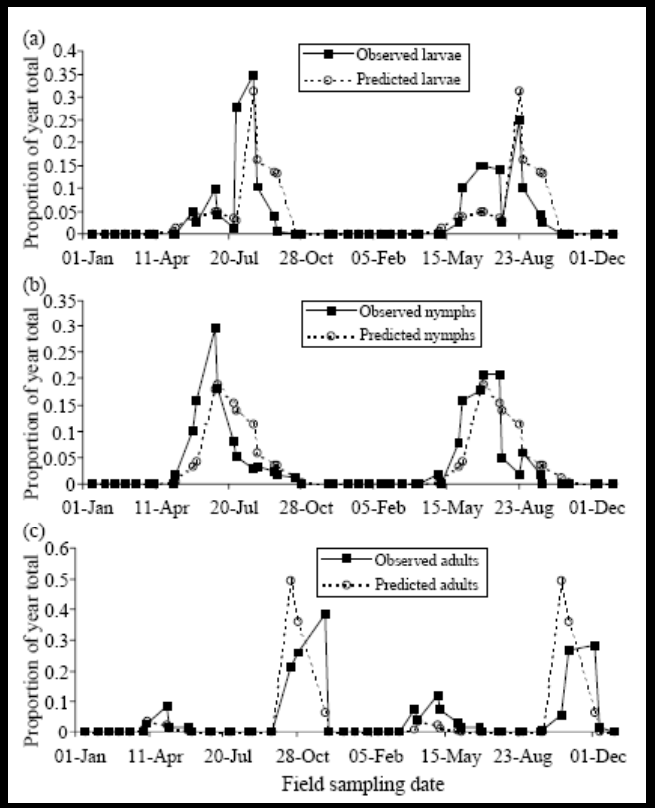
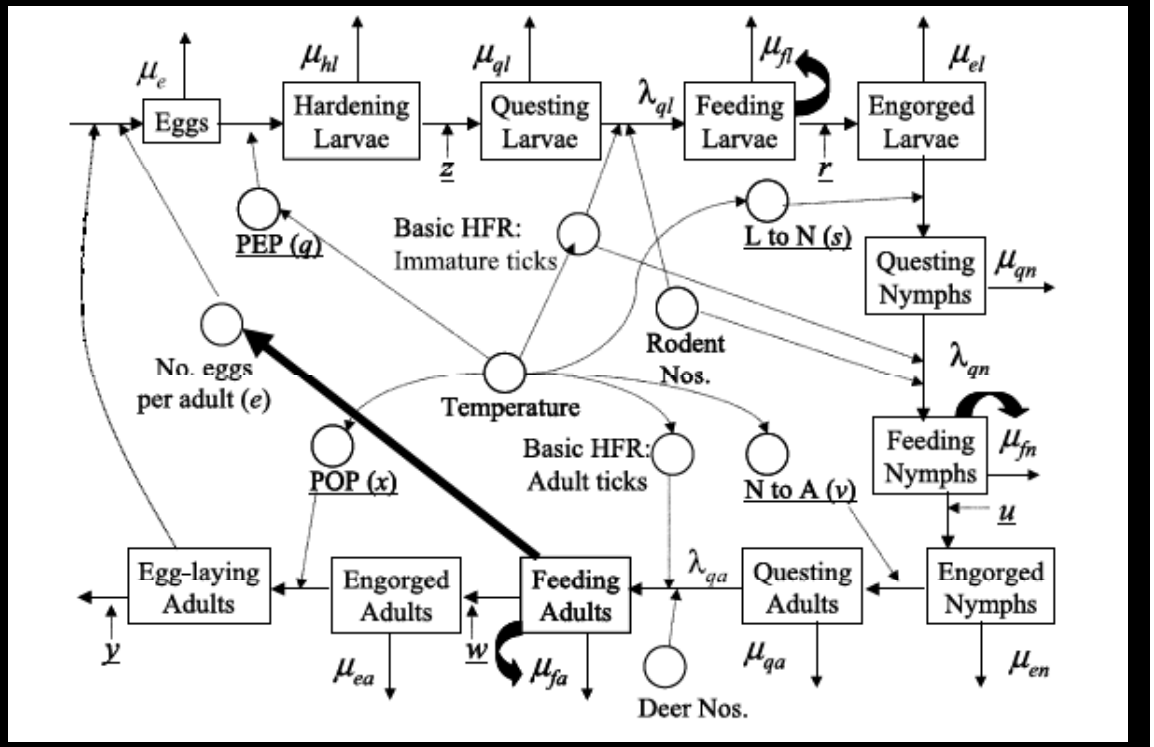
# a. Increased pathogen/vector proliferation and/or subsistence: expanded geographic range

## Vectors

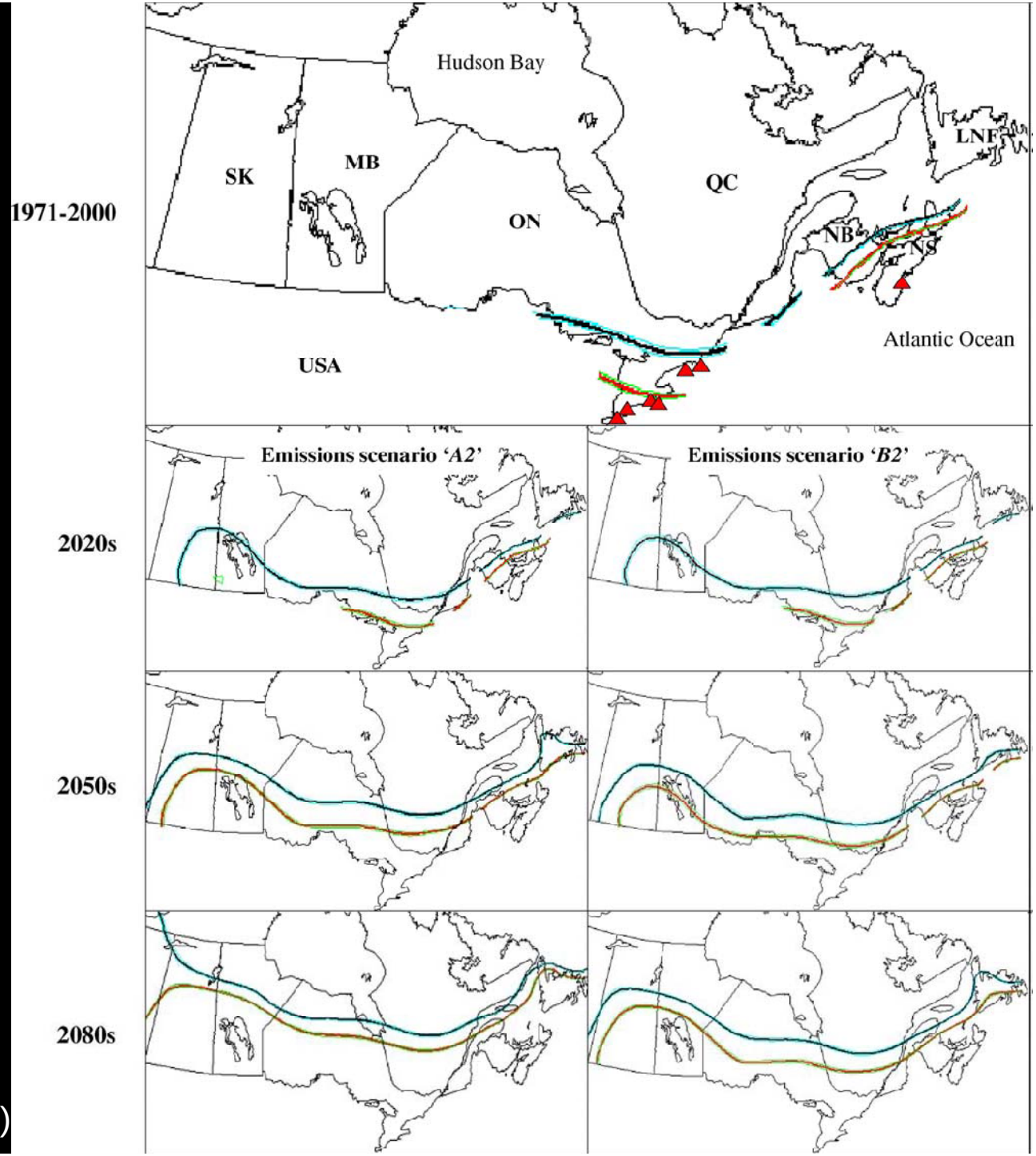




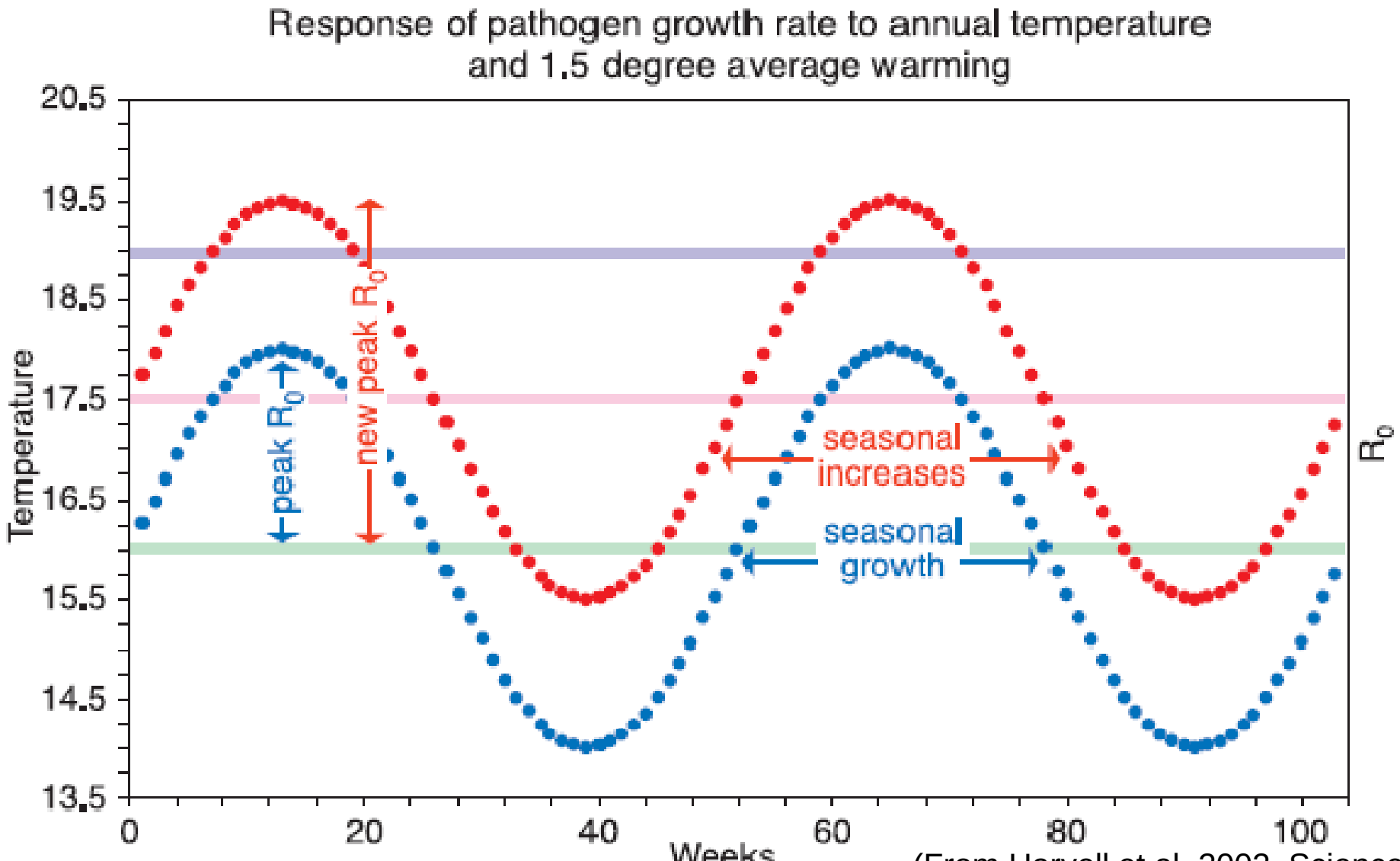

(Ogden et al 2005. Int J Parasitol)

# Vectors




(Ogden et al 2006. Int J Parasitol)

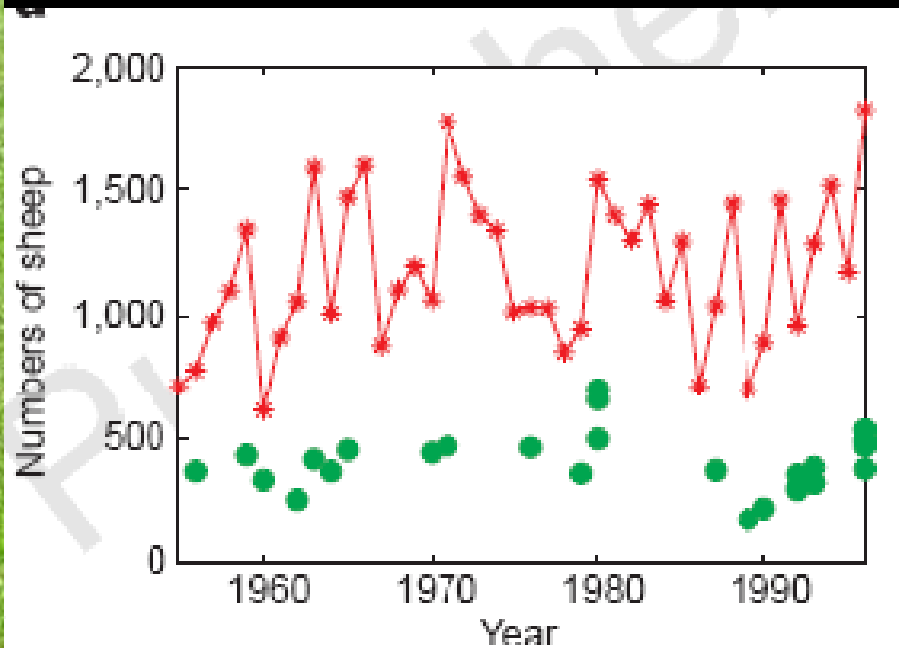
# a. Increased pathogen/vector proliferation and/or subsistence: expanded geographic range & seasonality




(From Harvell et al. 2002. Science)

# a. Increased pathogen/vector proliferation and/or subsistence: increased intensity/severity of infection

Feral Soay sheep in St. Kilda (Scotland)




(Grenfell et al 1998. Nature)

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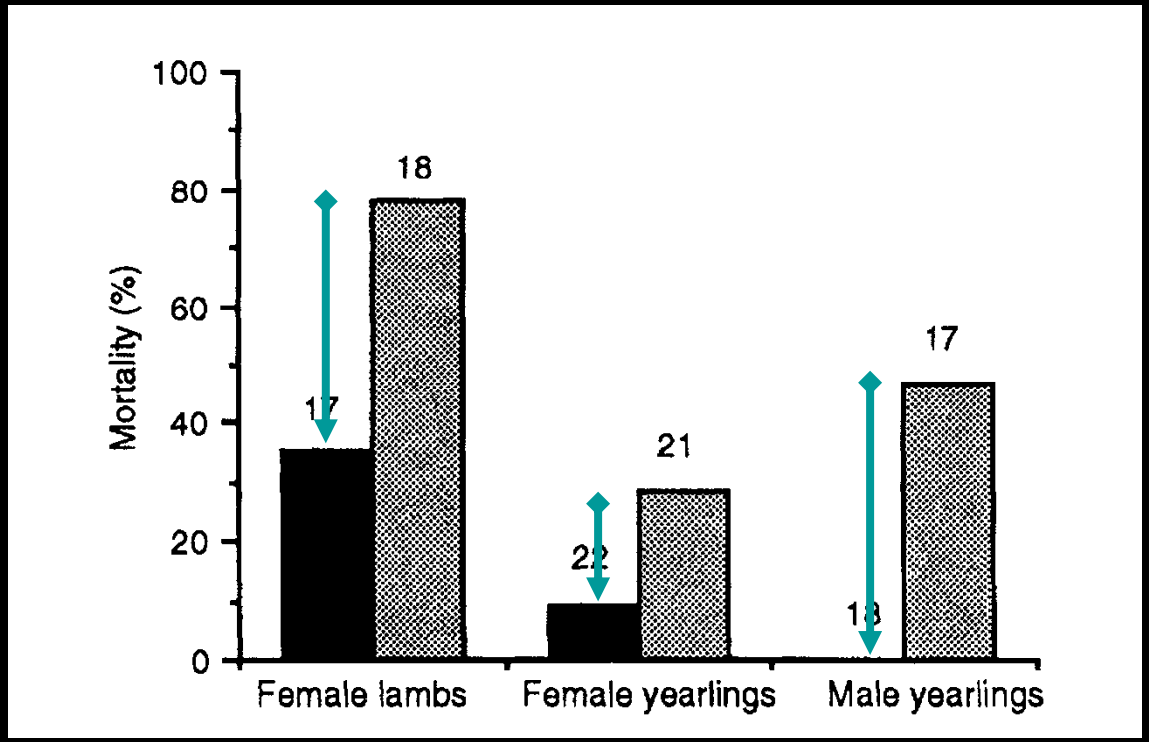
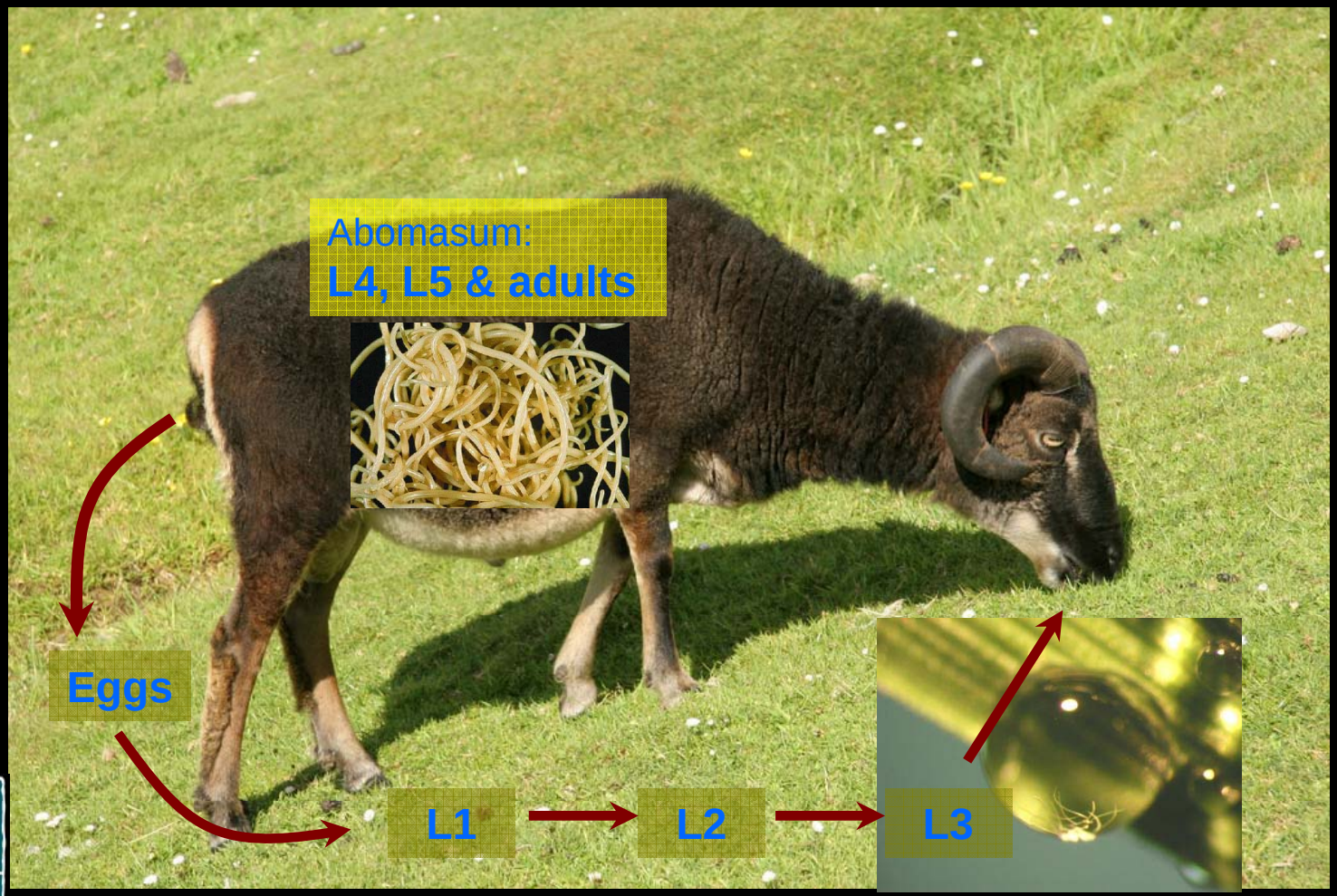
# a. Increased pathogen/vector proliferation and/or subsistence: increased intensity/severity of infection




(Gulland et al 1993. Proc R Soc Lond B)

# a. Increased pathogen/vector proliferation and/or subsistence: increased intensity/severity of infection

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# a. Increased pathogen/vector proliferation and/or subsistence: increased intensity/severity of infection

Increased precipitation

Increased larval subsistence

High parasite burdens

Elevated mortality

**MECHANISM a**: Increased pathogen/vector proliferation and/or subsistence

- Expansion in the geographic distribution of some pathogens
- Changes in the seasonality
- Increased severity of disease

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## b. Increased host susceptibility to infection: increased exposure

# Changes in host behaviour favouring pathogen transmission

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## b. Increased host susceptibility to infection: increased exposure

# Changes in host behaviour favouring pathogen transmission

**Walruses prey more on ringed seals, increasing the risk of trichinellosis (Rausch et al 2007. Parasitol)**

## b. Increased host susceptibility to infection: increased exposure

**Some host species and their parasite communities are expanding their distribution**

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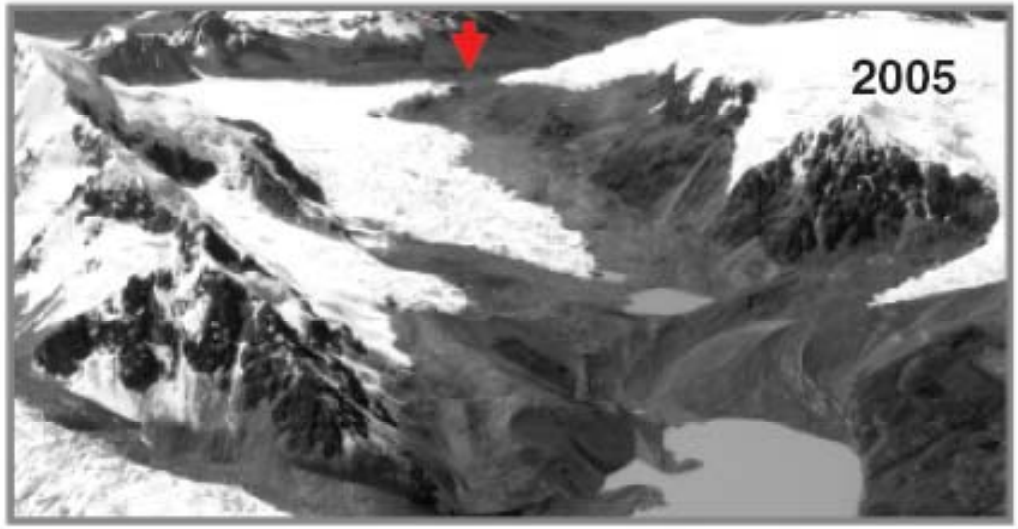
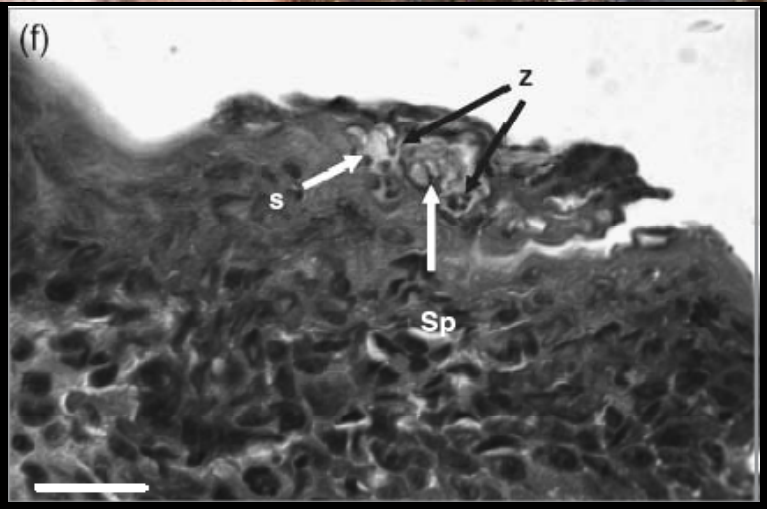
# *Batrachochytrium dendrobatidis* reaching unprecedented altitudes in Perú






(Seimon et al 2007. Glbl Chng Biol)

# b. Increased host susceptibility to infection: Affected host vulnerability

↑ Stress = ↓ Immunocompetence

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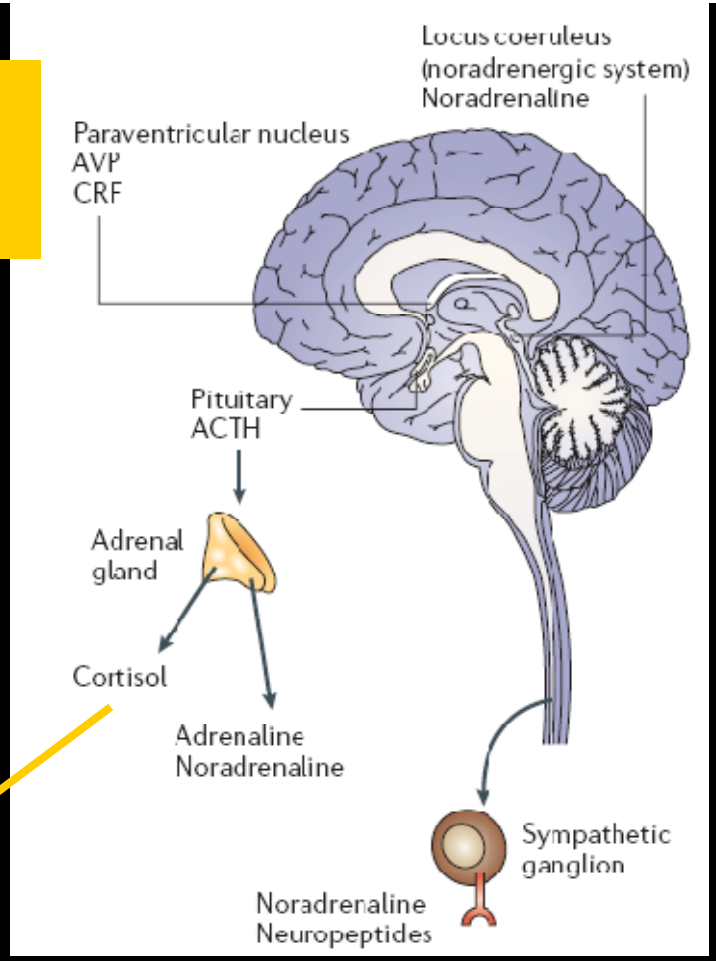
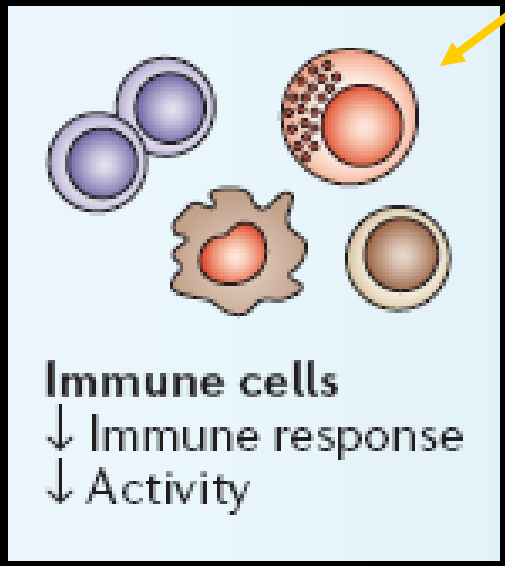
# How would climate change affect host resistance?

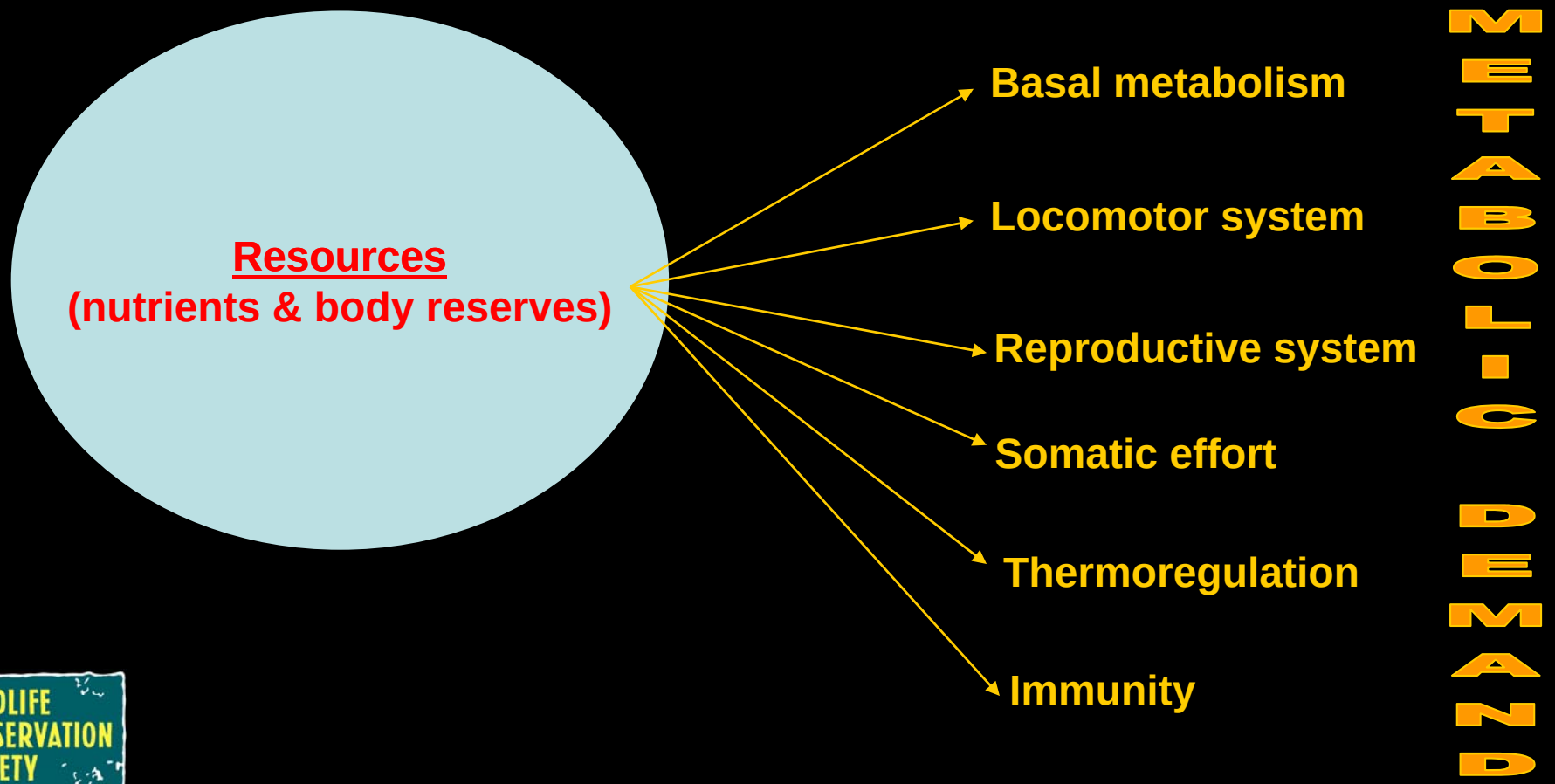



Figures: Antoni et al 2006. Nat Rev Cancer

# How would climate change affect host resistance?

## trade-offs: physiological economy

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# THE VICIOUS CIRCLE THEORY

**Stress (e.g. by climate disturbance)**

Poor condition

Infection

DEATH

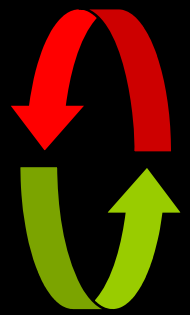
Poor performance

Poor population growth

Low host densities

(Beldomenico et al, 2008. Proc R Soc B & Beldomenico et al, in review)

# THE VICIOUS CIRCLE THEORY



Month 1

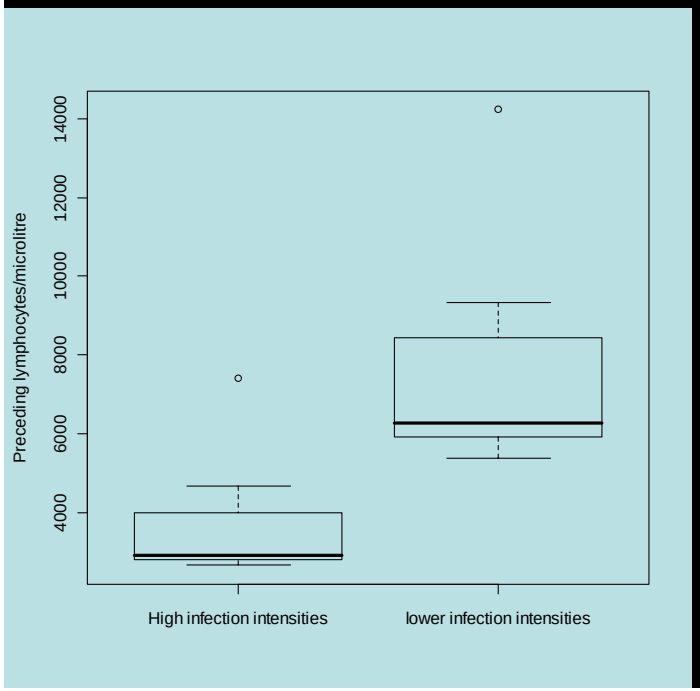
Immunosuppresion

Month 2

Severe infection

Month 3

Immunosuppresion




(Beldomenico et al, in review)

# Effects of climate change

- Expansion in the geographic distribution of some pathogens
- Changes in the seasonality
- Increased severity of disease
- Increased exposure to pathogens
- Increased host vulnerability

Affected dynamics of health

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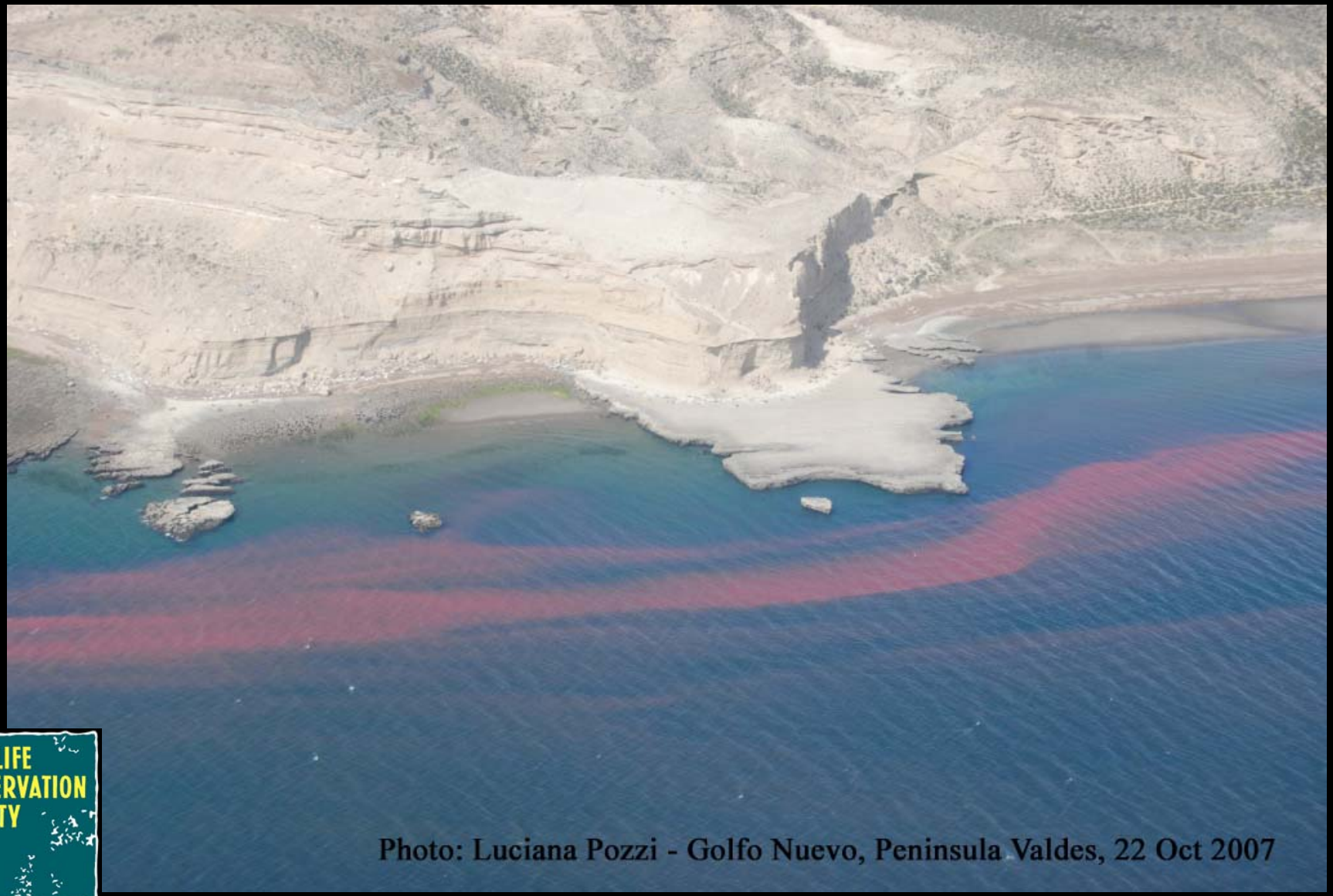
# *Conservation problems arising from wildlife health disruption*

# Sea surface temperature favoring the proliferation of some disease agents

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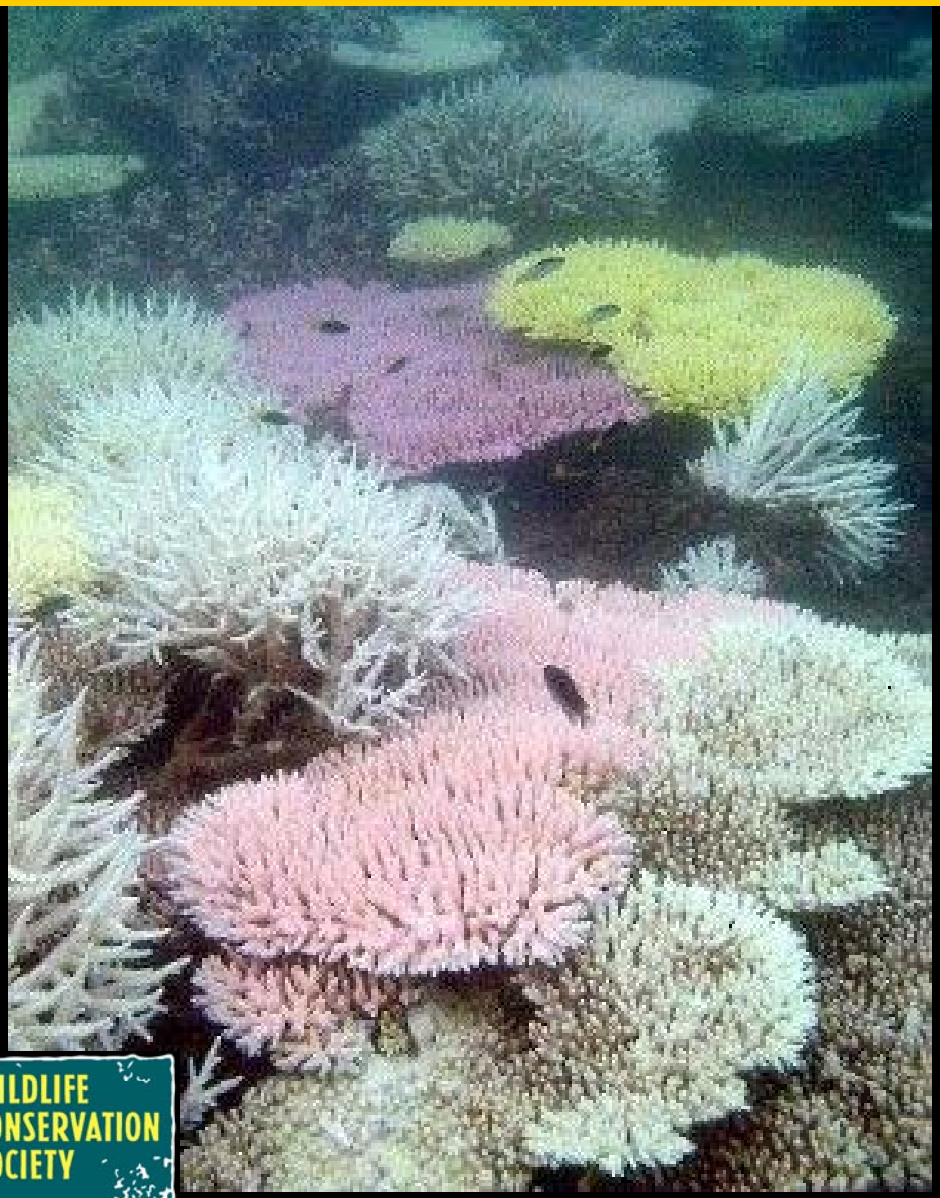
# Sea bird mortality in the South Atlantic

neosaxitoxin (NeoSTX)
gonyautoxin 4 (GTX4)

# CORAL BLEACHING



- High sea surface temperature
- $CO_2$ increase

**Coral bleaching**

(Anthony et al, 2008. PNAS)

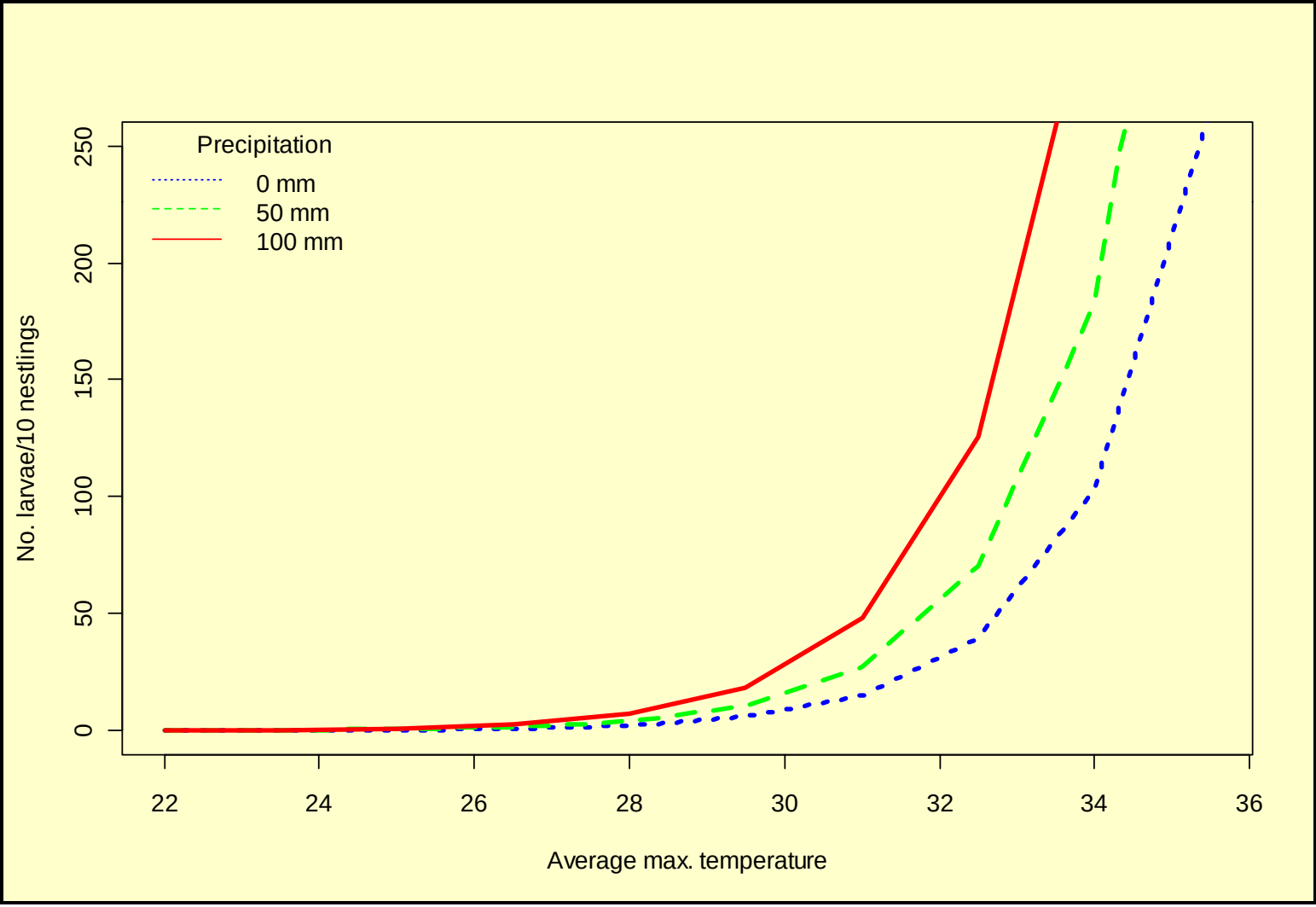
# Increased ectoparasitism in birds

***Philornis* spp. botflies**

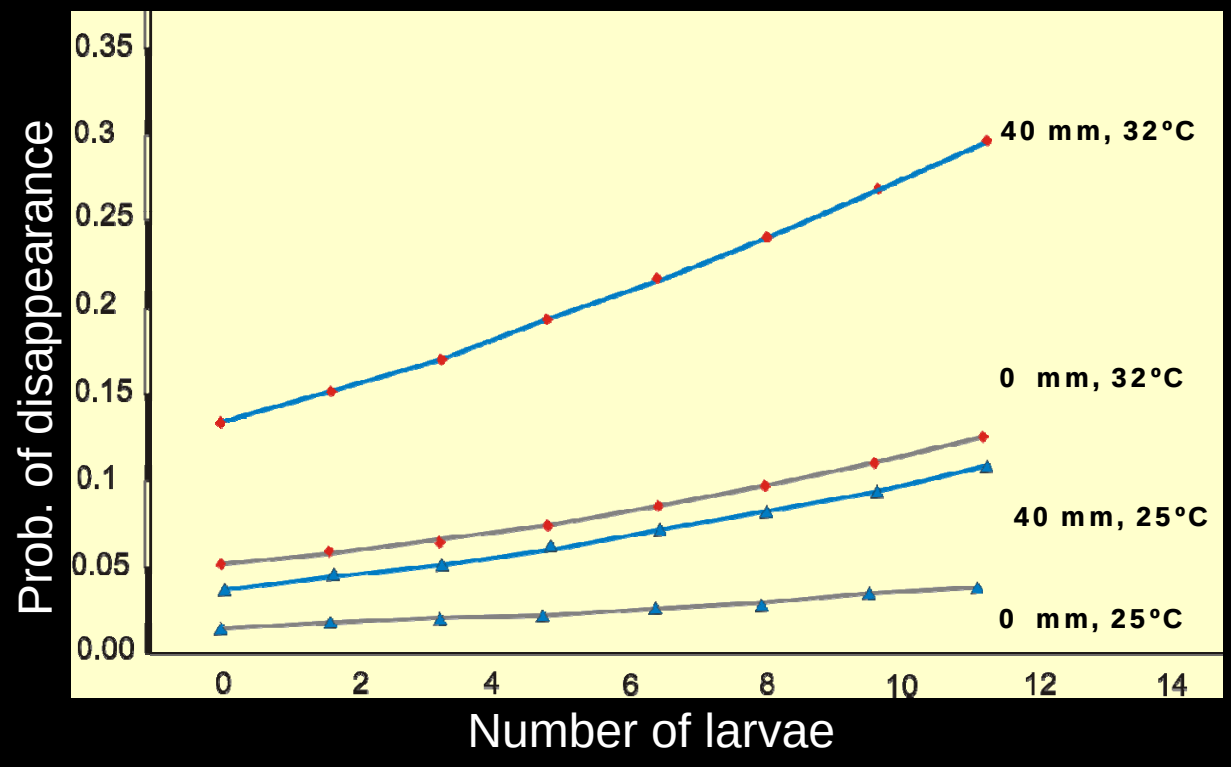
Anecdotal evidence suggests that this parasitism has become more frequent in southern S.A.

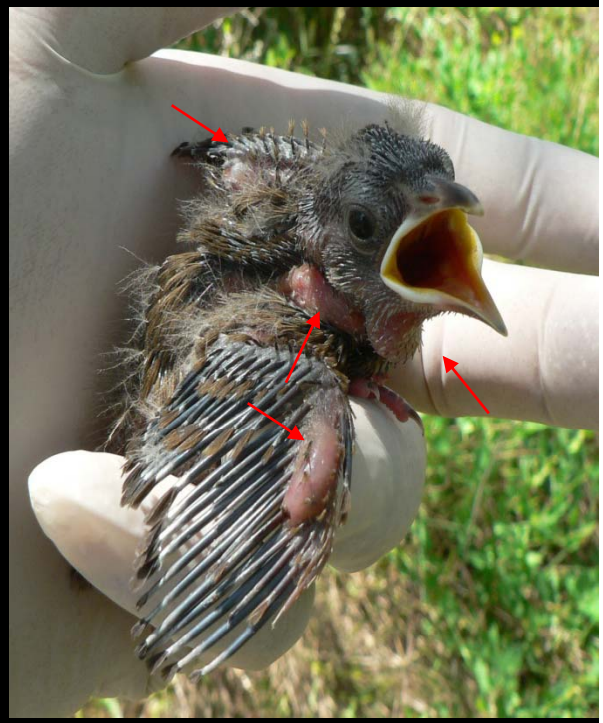
# Climate and parasite abundance

The intensity of *Philornis* parasitism depends on temperature and rainfall

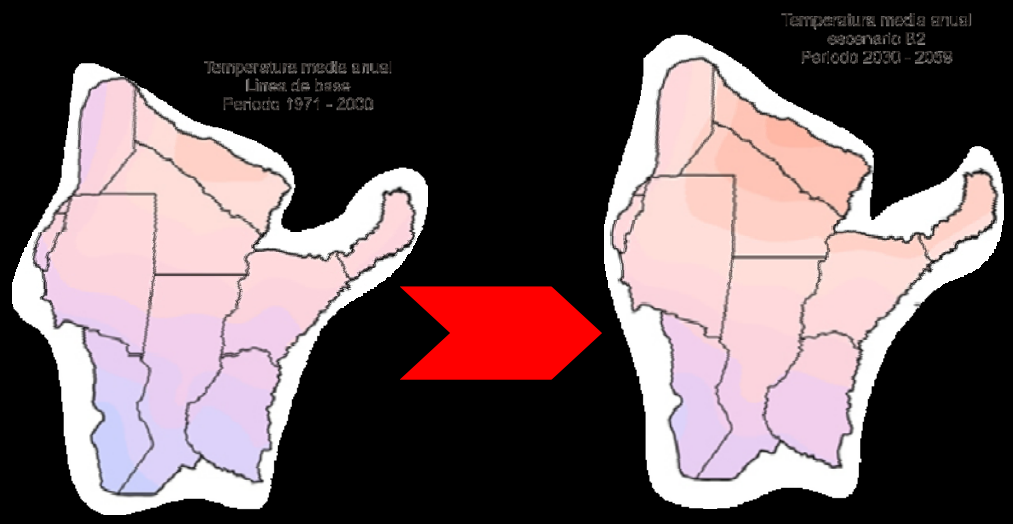


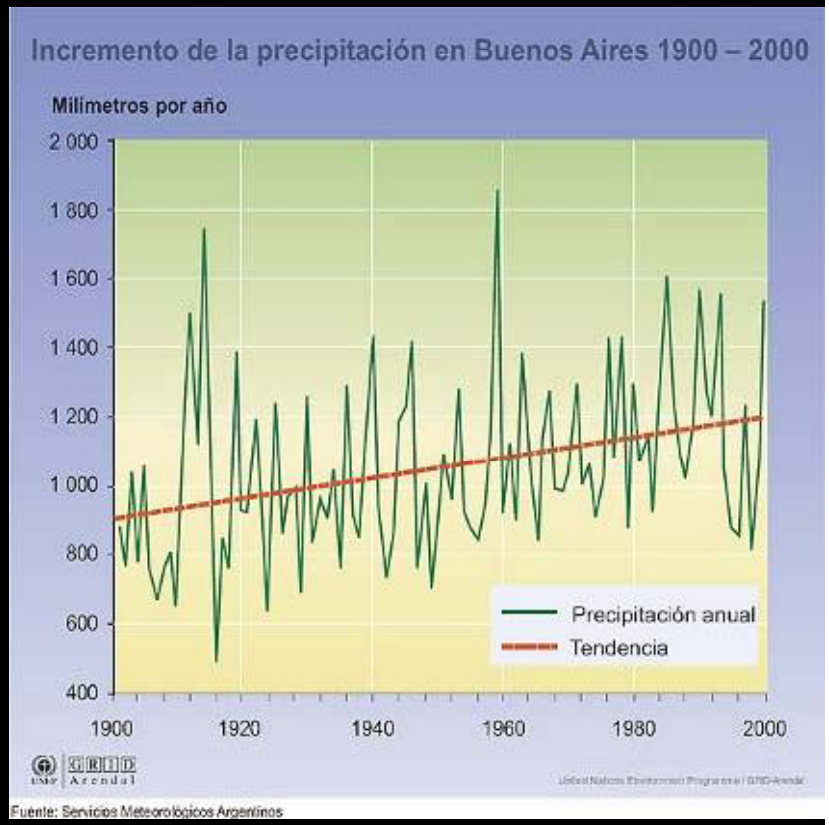
# More botflies are associated with more mortality



# More heat and precipitation → More botflies → More nestling mortality




(From Servicios Meteorológicos Argentinos)

# Regarding host susceptibility...

**THE VICIOUS CIRCLE THEORY**

Keeping a good condition is important to avoid infections, and avoiding infections is essential to keep in good condition

**If climate change impoverishes the condition of most individuals in a population, then vicious circles may be triggered and the population will decline**

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# Worldwide amphibian declines

In the last decades, thousands of amphibian spp have declined

- 447 spp. critically endangered
- 122 spp. Possibly extict

(Global Amphibian Assessment)

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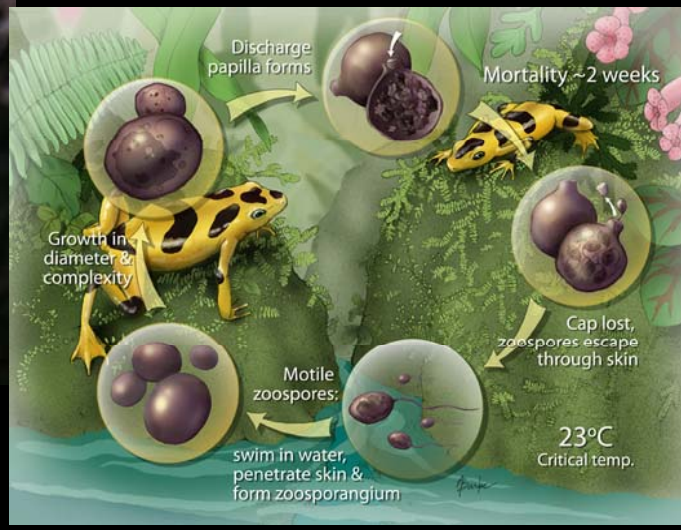
# Worldwide amphibian declines

**The spreading pathogen hypothesis** (Lips et al 2008. PLoS Biol)

**The climate-linked epidemic hypothesis** (Pounds et al 2006. Nature)

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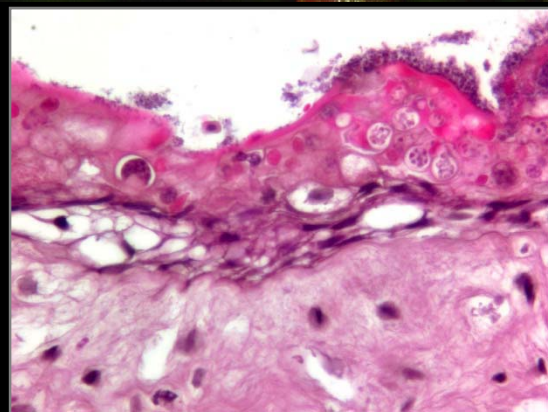
# Worldwide amphibian declines

**Declining populations showed greater prevalences of:**

***Saprolegnia ferax*** **(Kiesecker et al 2001)**

- ***Basidiobolus ranarum*** **(Taylor et al 1999)**
- ***Amphibiocystidium ranae*** **(Di Rosa et al 2007)**
- **Ranaviral disease (Daszak et al 1999)**
- **Nematodes (Garcia et al 2007)**
- **Acantocephalans (Garcia et al 2007)**



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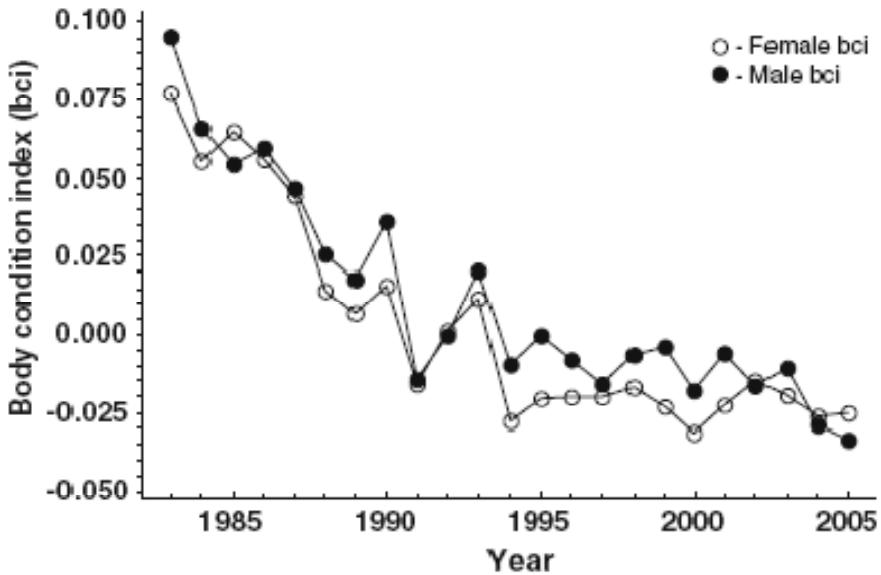
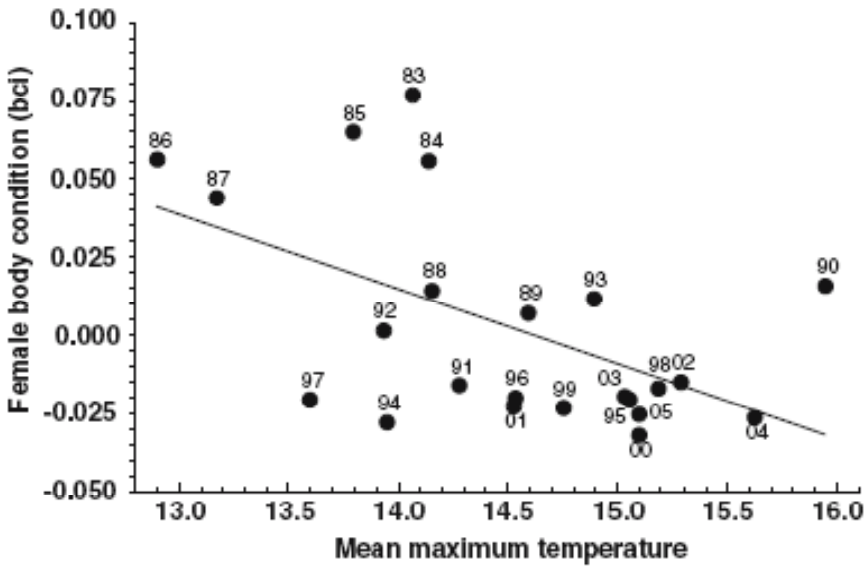
# Worldwide amphibian declines & vicious circle

**Global warming affects condition of amphibians**
(Reading 2007. Oecologia)

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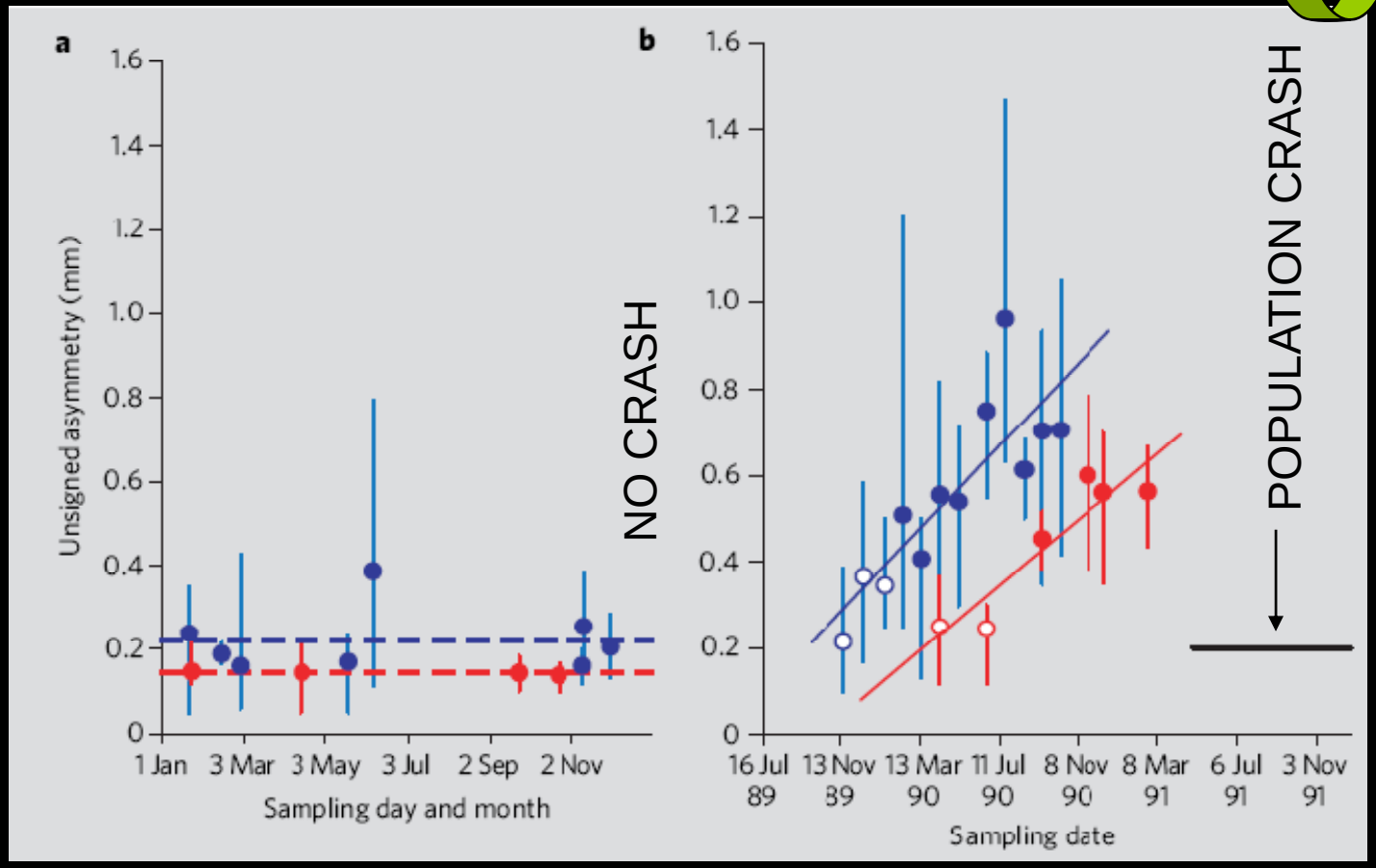
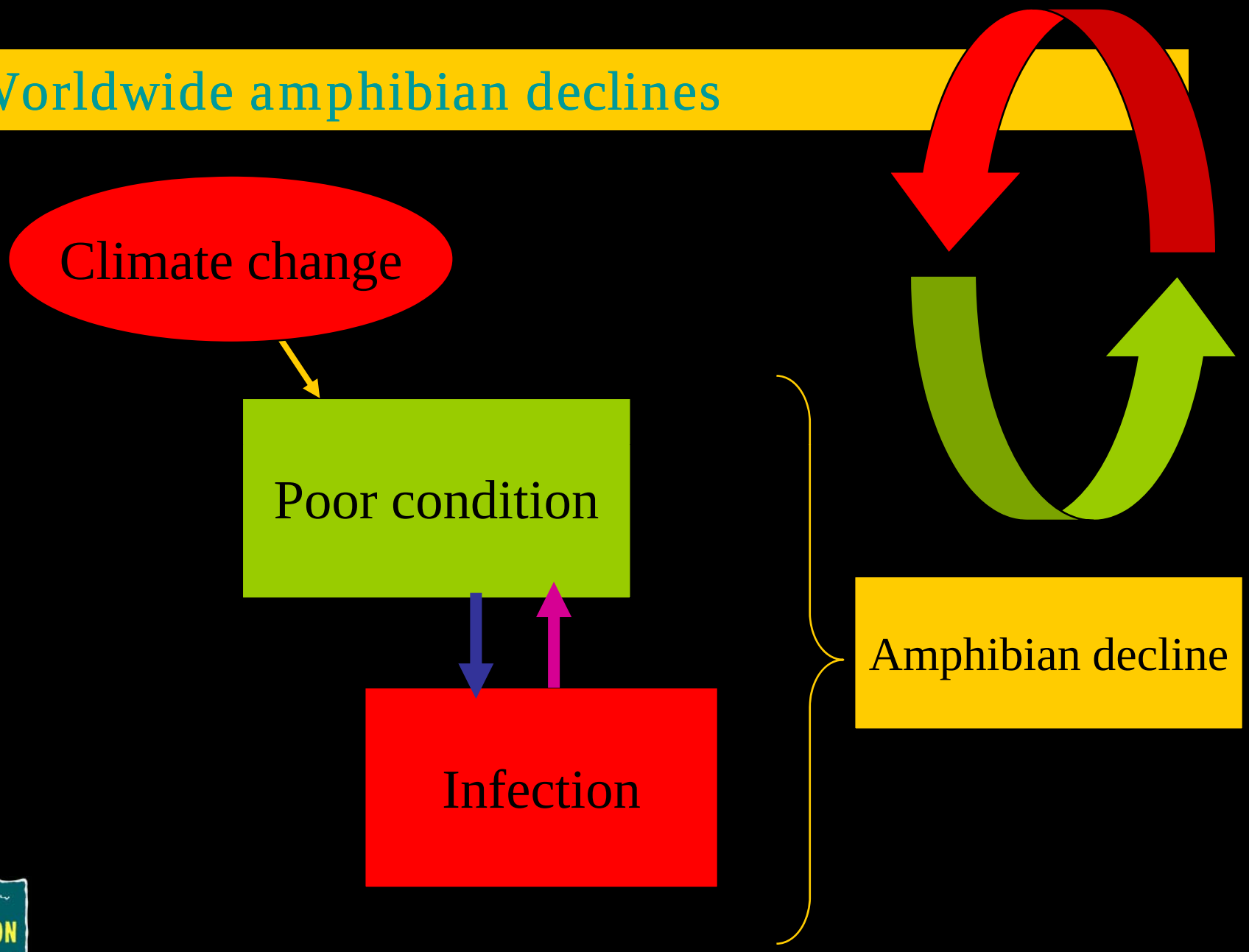
# Worldwide amphibian declines

## Declines are preceded by increased stress

(Alford et al 2007. Nature)



# Worldwide amphibian declines

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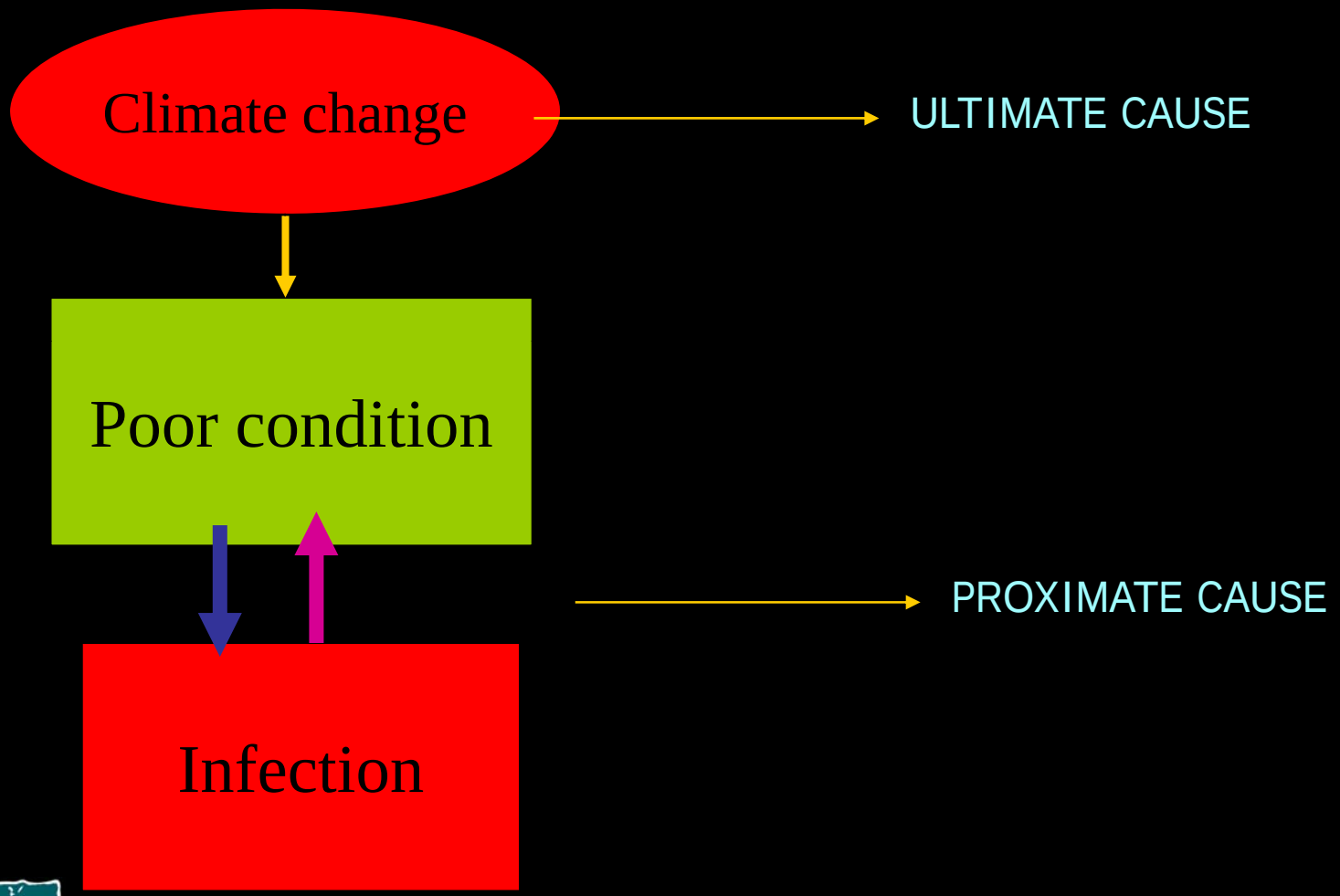
# Worldwide amphibian declines

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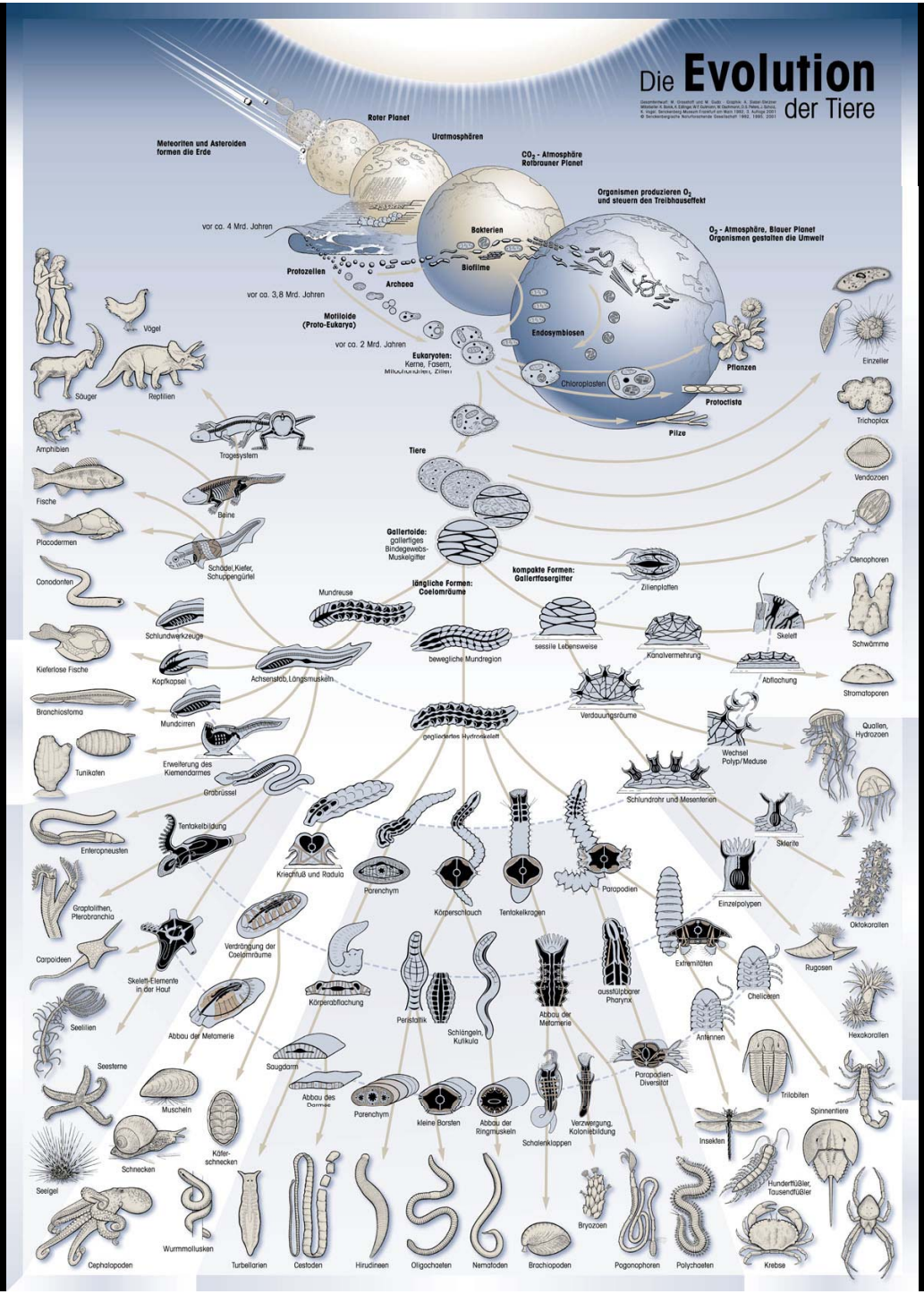
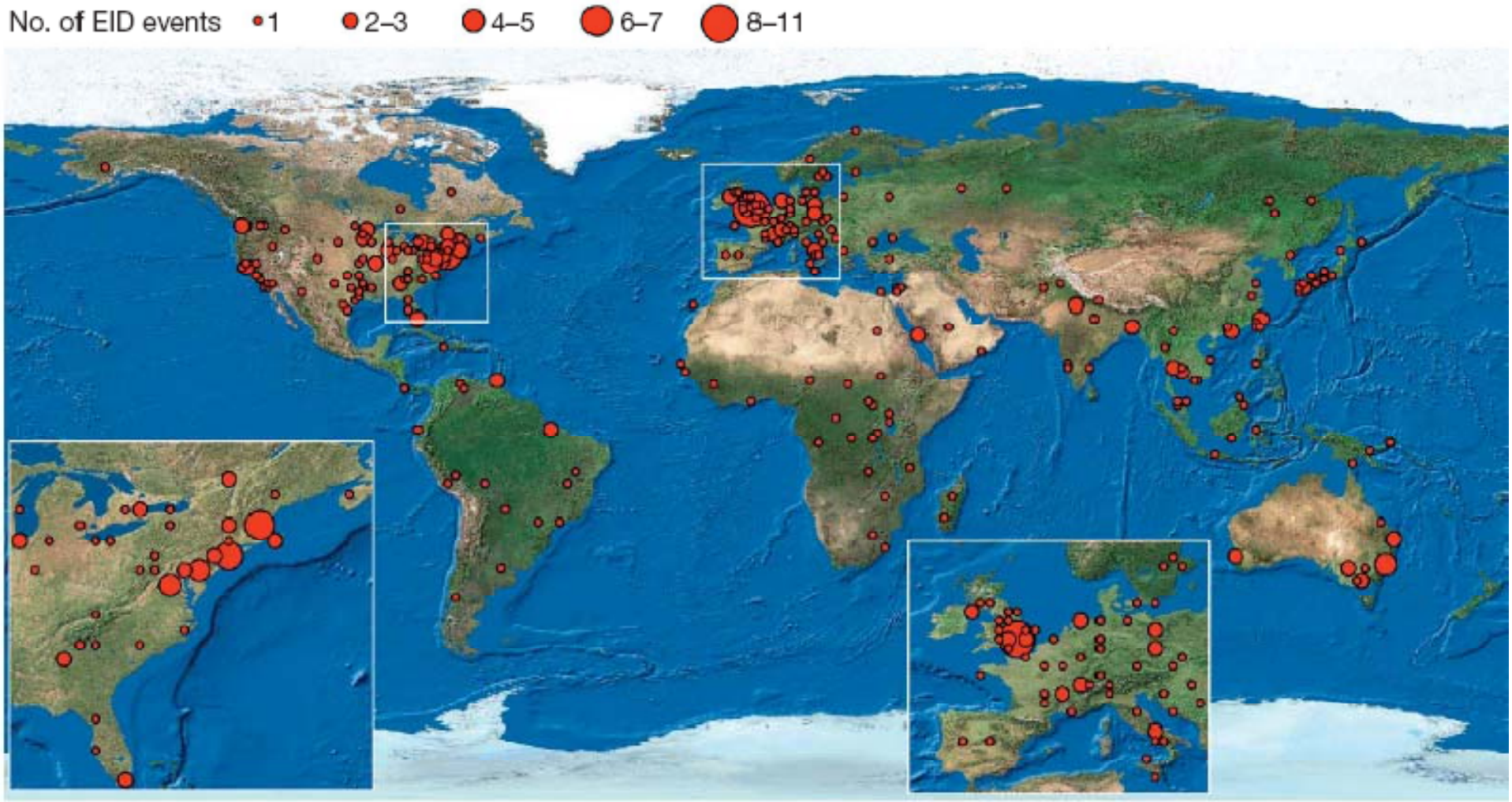



(Figure: M. Gudo ®)

# *Implications for livestock and human health*

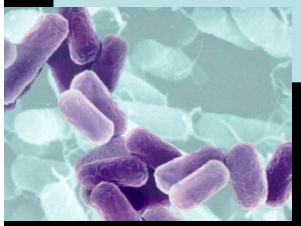
# EIDs

335 emerging infectious diseases since 1940,
145 from wildlife (Jones et al 2008. Nature)



# Why do zoonotic diseases emerge or re-emerge?

INCREASED CONTACT WITH PATHOGENS



•Changes in human behavior

• Climate change

• Landscape modification

• Urbanization

• Travel and trade

Friend, 2006

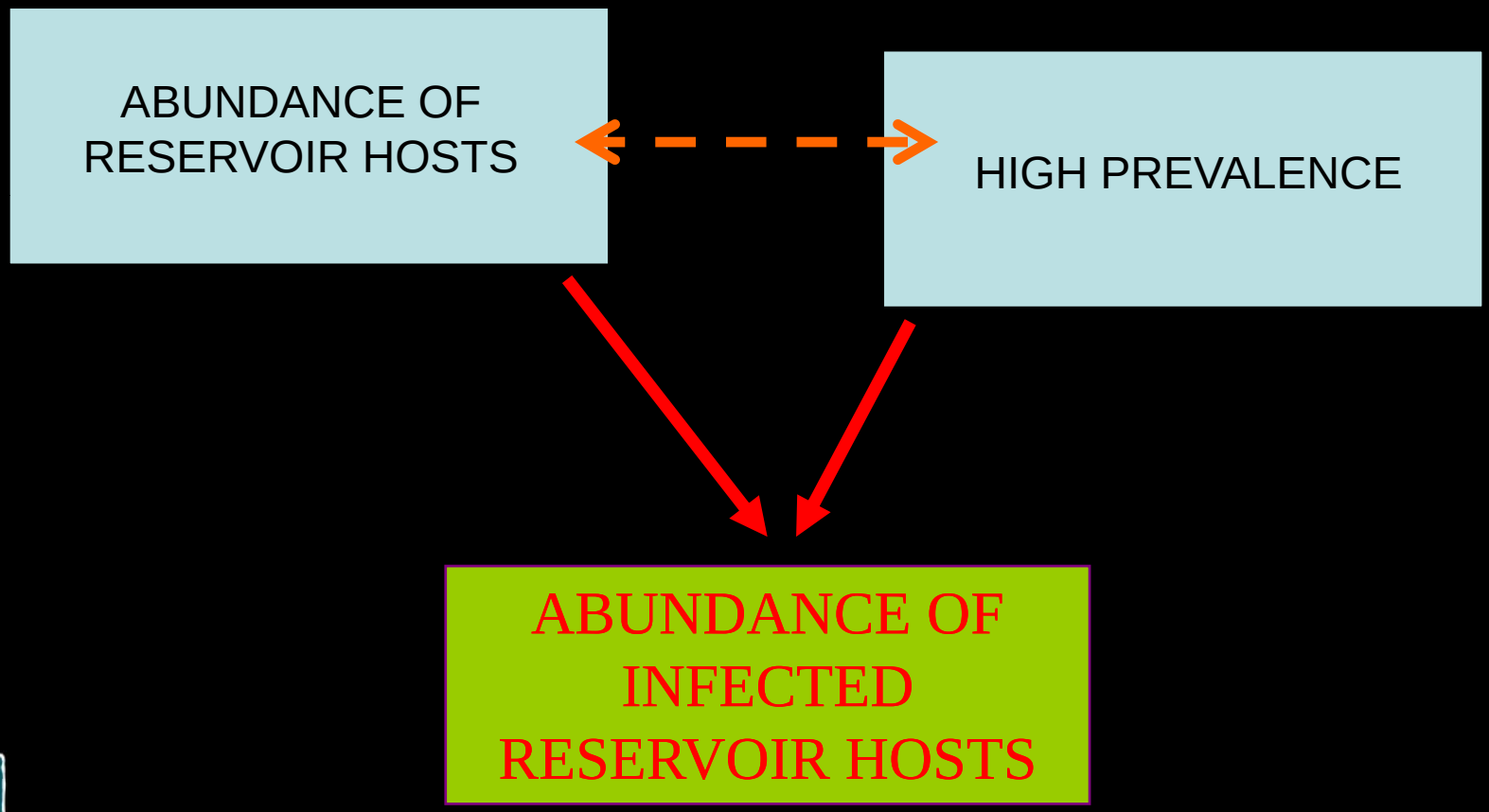
# When does the risk of acquiring a zoonotic disease from wildlife increase?

ABUNDANCE OF INFECTED RESERVOIR HOSTS

INCREASED CONTACT WITH PATHOGENS

WILDLIFE CONSERVATION SOCIETY

# When are infected reservoir hosts abundant?

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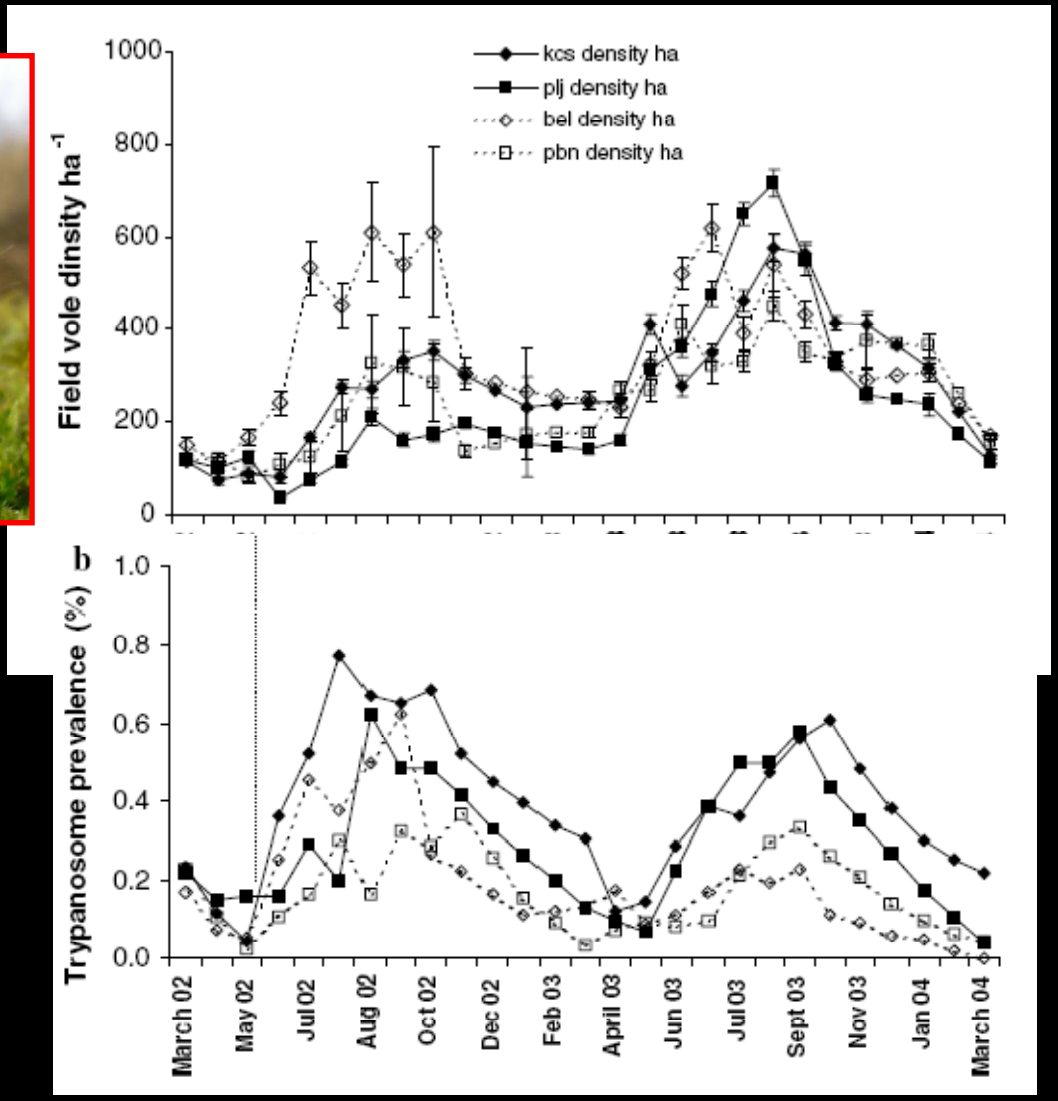
# SYNERGISM BETWEEN ABUNDANCE AND PREVALENCE




Smith et al, 2006. Parasitol

# Why the synergism between abundance and prevalence?

AT HIGHER DENSITIES:
MORE CONTACT BETWEEN INDIVIDUALS

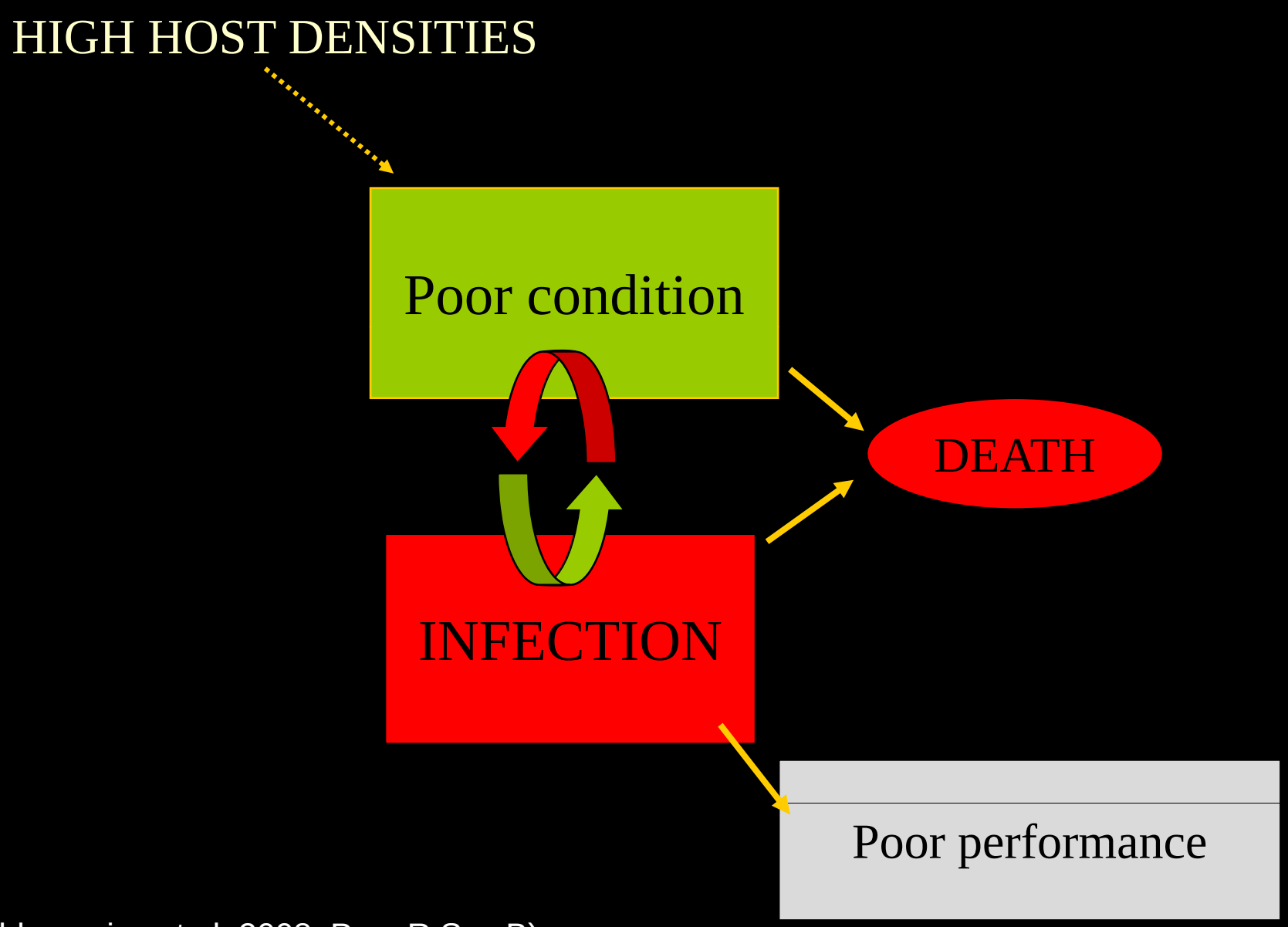
(Anderson & May, 1979. Nature)

&

AT HIGHER DENSITIES:
IMPOVERISHED CONDITION (STRESS AND LESS RESOURCES)

WILDLIFE CONSERVATION SOCIETY

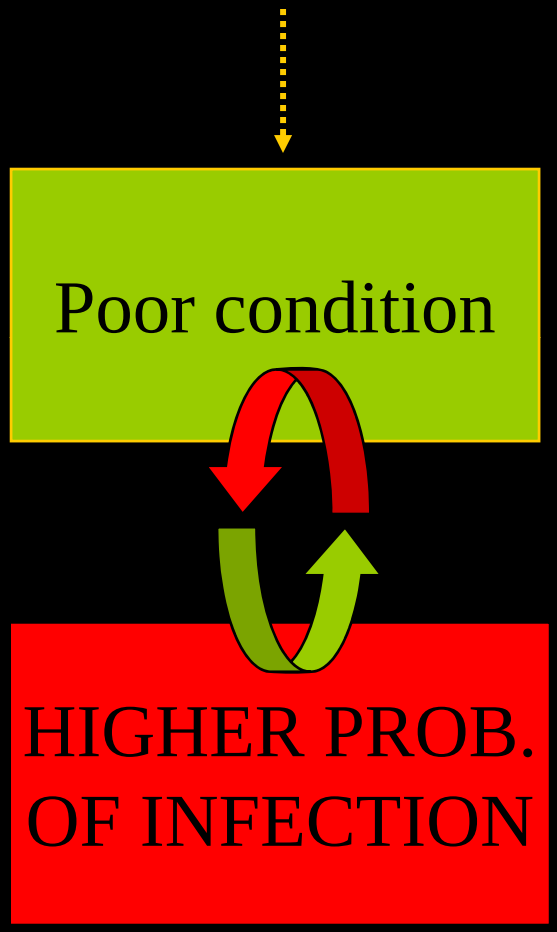
# THE VICIOUS CIRCLE

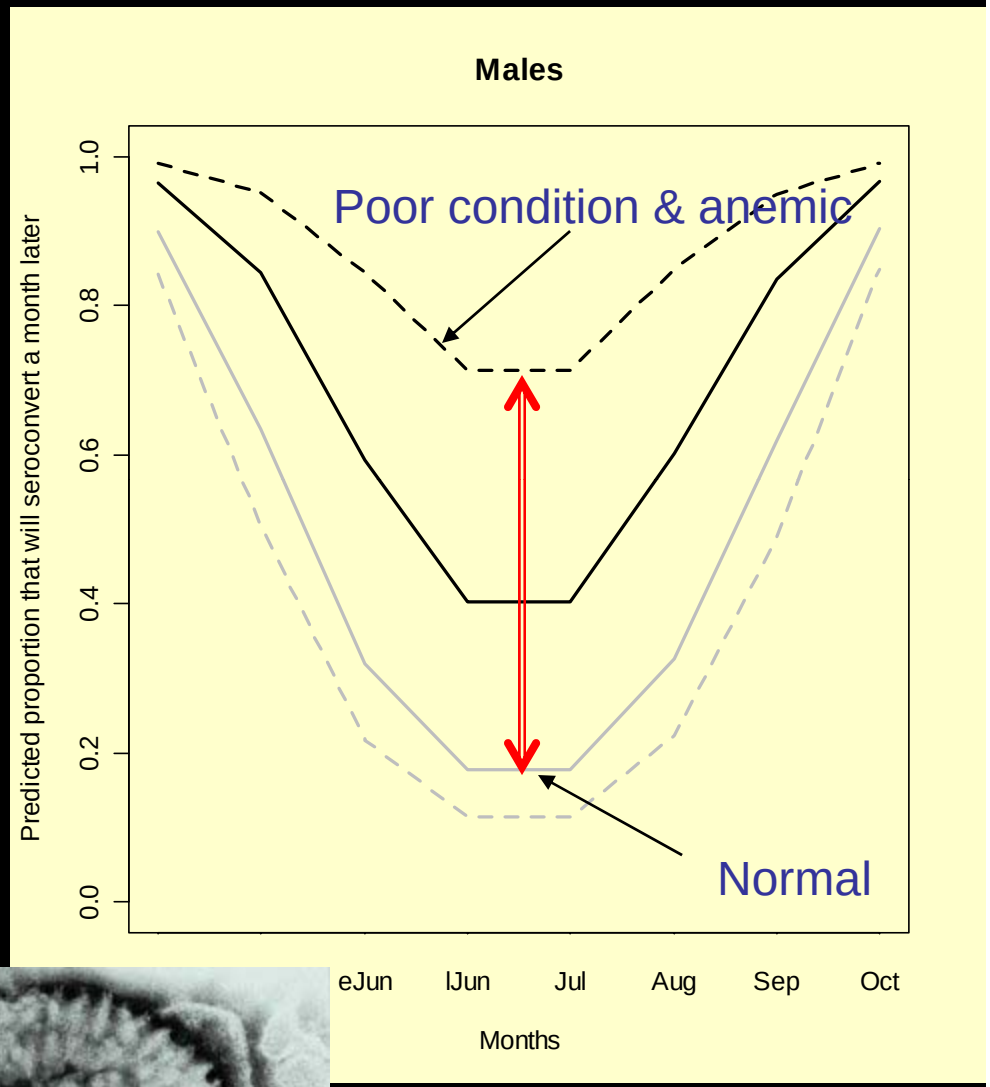


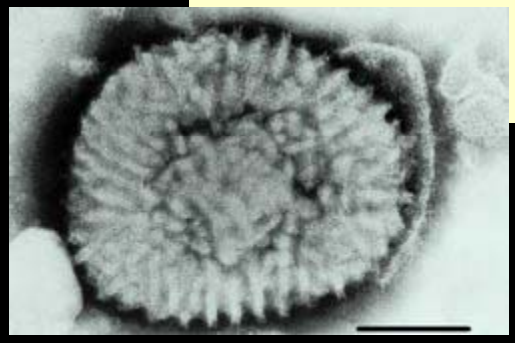

(Beldomenico et al, 2008. Proc R Soc B)

# THE VICIOUS CIRCLE

HIGH HOST DENSITIES



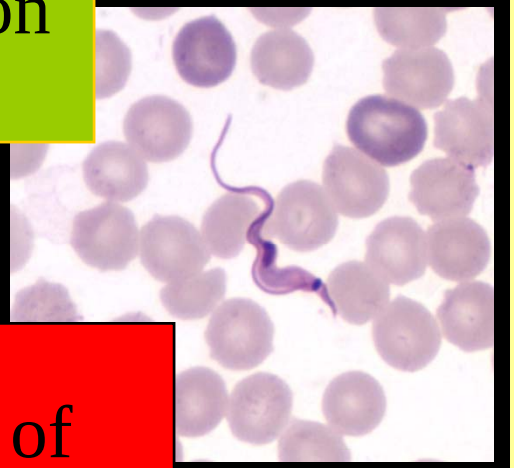



Beldomenico et al, in press. Epidemiol Infect

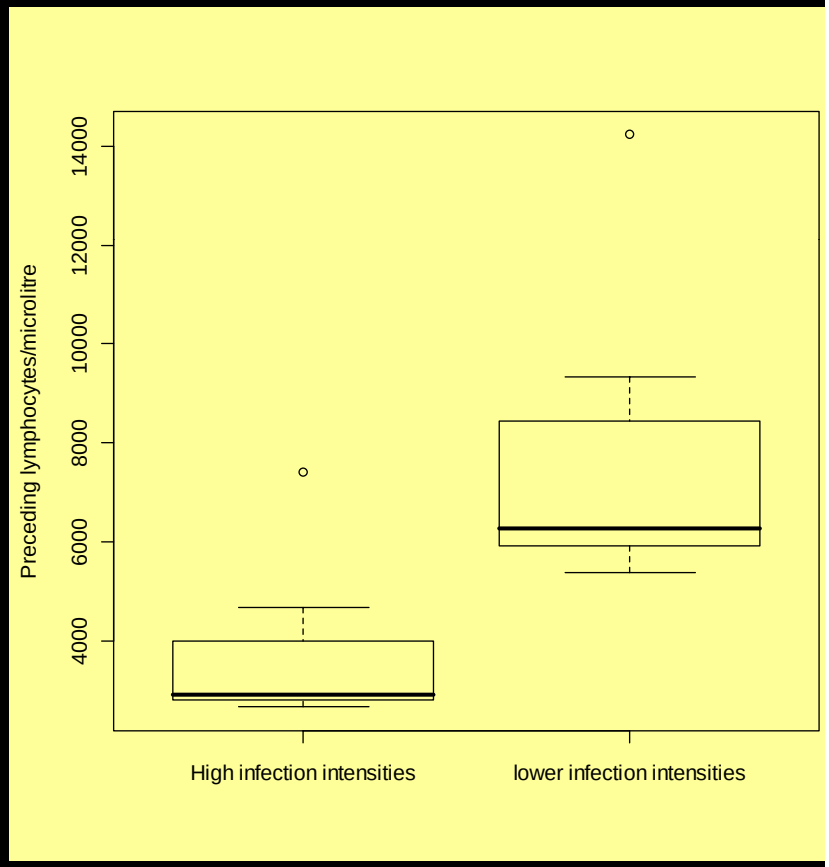
# THE VICIOUS CIRCLE

HIGH HOST DENSITIES

Poor condition



INFECTIONS of HIGHER INTENSITY




Beldomenico et al, in review

# SUMMARIZING

HIGH HOST DENSITY

↓

HIGH PREVALENCES & INFECTIONS of HIGH INTENSITIES

ABUNDANCE OF INFECTED RESERVOIRS

↓

> PROBABILITY OF CONTACT WITH THE PATHOGEN

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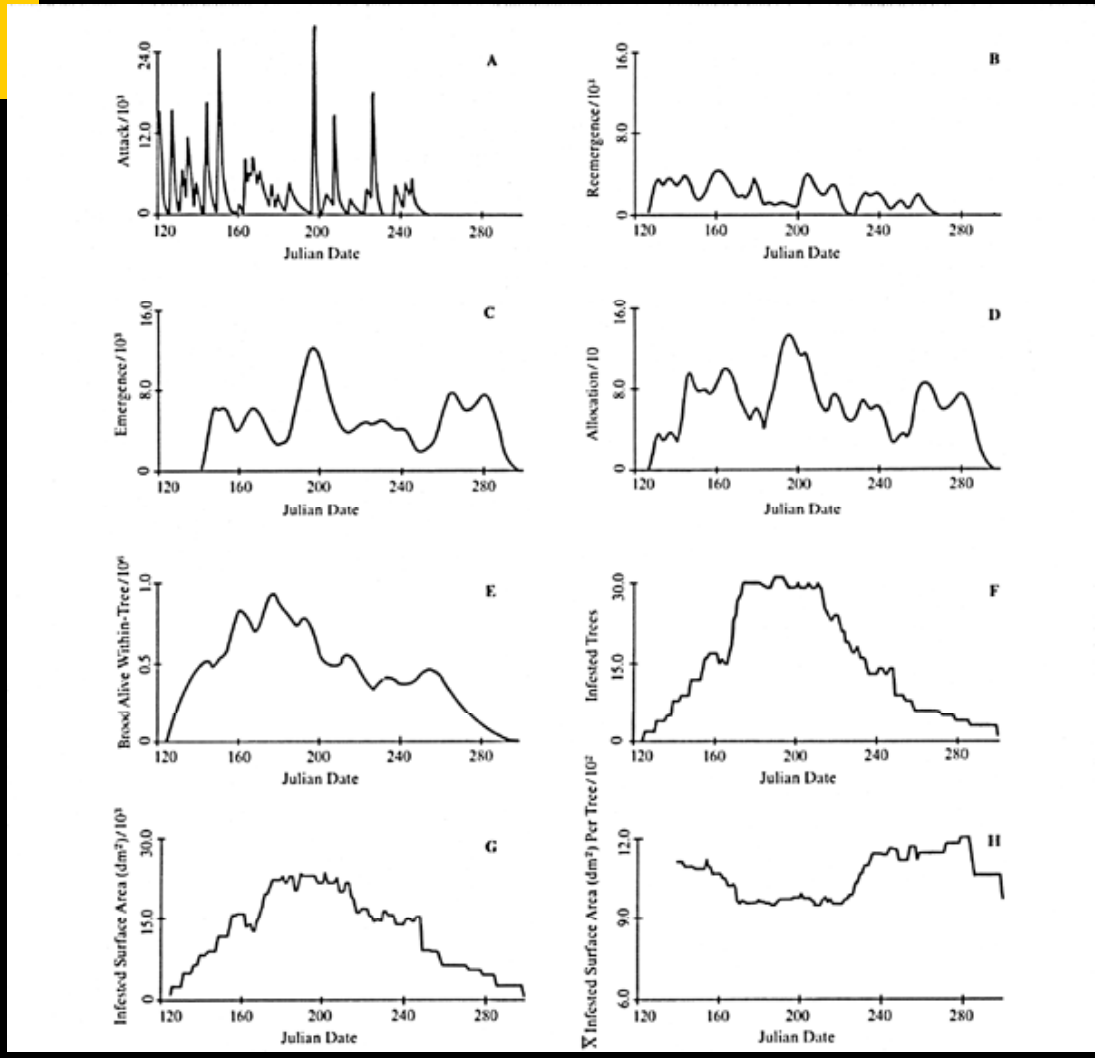
# What causes host abundace to peak?



# ECOSYSTEM DISTURBANCE

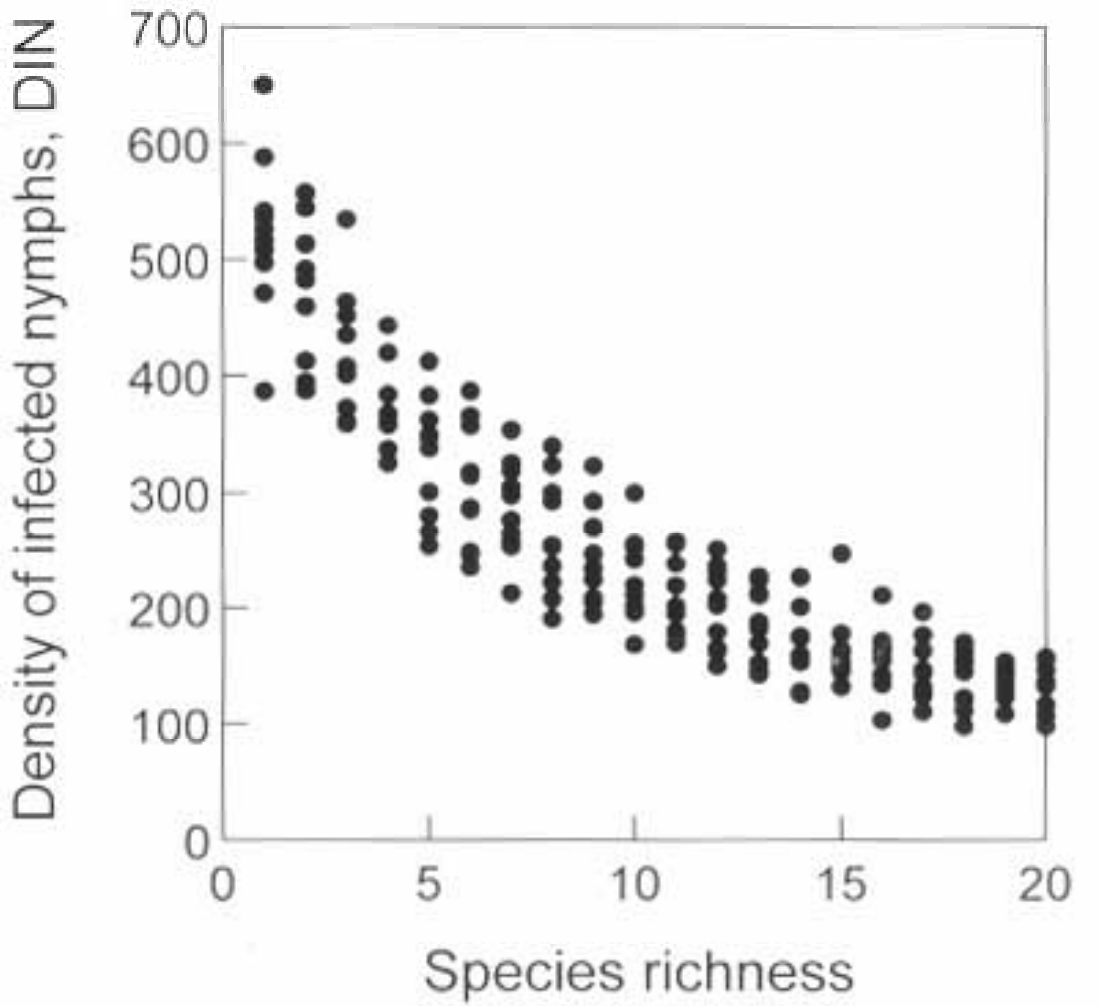
- *ARGENTINE HEMORRHAGIC FEVER*

# ECOSYSTEM DISTURBANCE

## LOSS OF THE DILUTION EFFECT

**Vector-borne pathogens**

**Specialist pathogens**



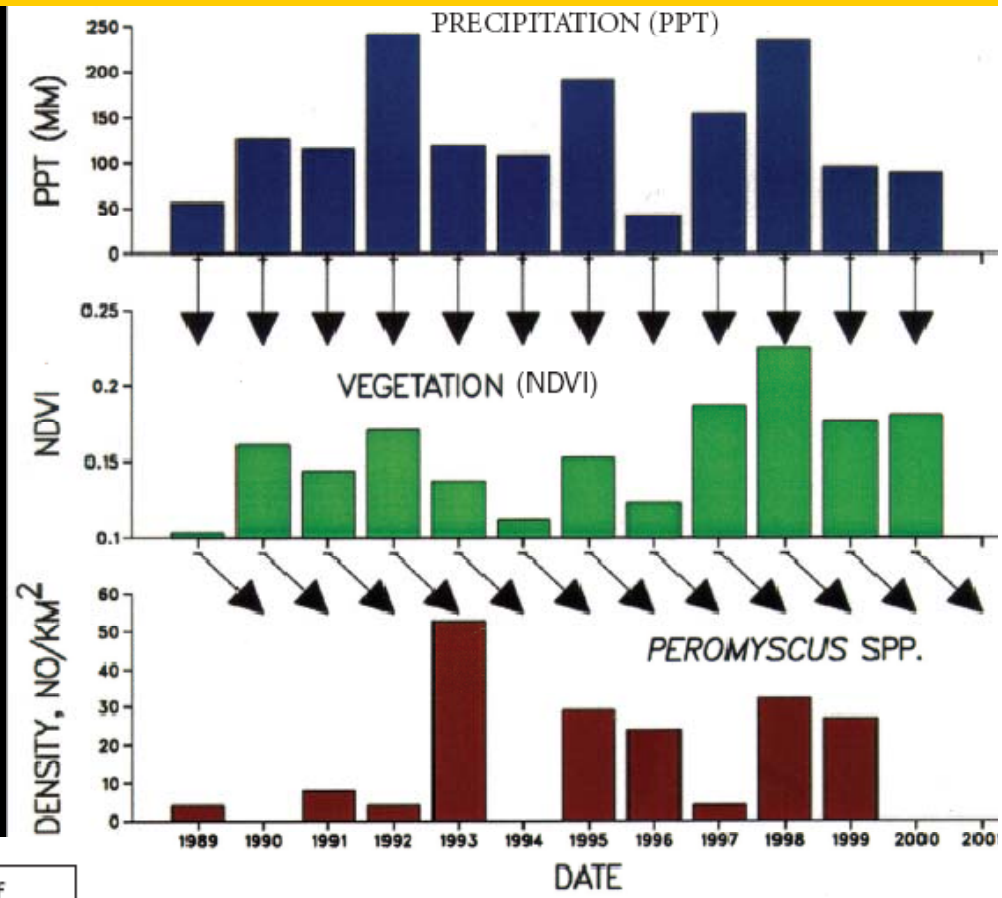

**Computer simulation results showing how increasing vertebrate diversity reduces risk of exposure to Lyme disease**

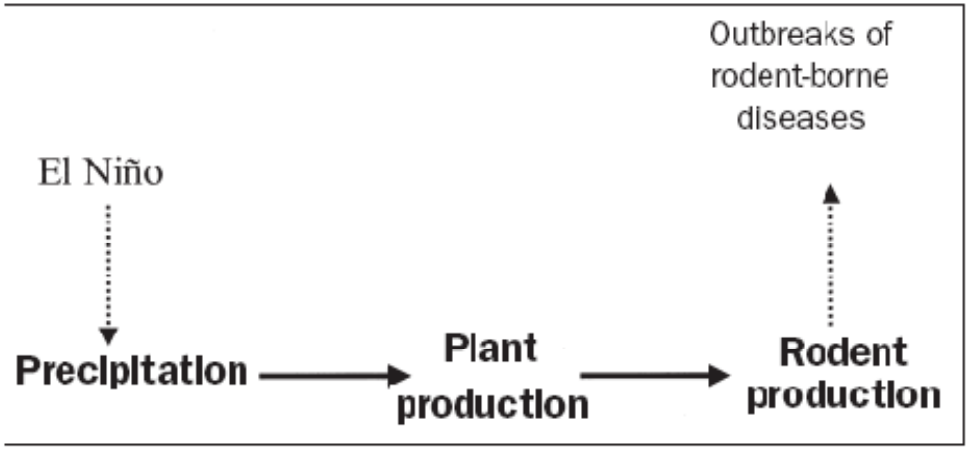
**From Schmidt and Ostfeld 2001.**

Schmidt & Ostfeld, 2001. Ecology
Keesing et al, 2006. Ecol Lett

# CLIMATE

**RATADAS**




Brown & Ernest 2002. Bioscience
Yates et al 2002. Bioscience

# Concluding

**Climate change has the potential to cause health problems when circumstances determine:**

- Hosts to be more susceptible
  *e.g.* amphibians
- Pathogens and vectors to be favored
  *e.g.* Cholera, Bluetongue, Dengue fever
- Reservoir species to proliferate
  *e.g.* Hantavirus reservoir hosts

# Concluding

**What will be the net effect of climate change on disease dynamics for a determined wildlife species?**

- We need to conduct much more research to be able to give a sensible answer.

# Concluding

Studying and monitoring health dynamics in natural systems is important to:

- be able to better understand health phenomena in intervened systems (human and livestock).

- be able to understand the determinants of disease variation in wildlife populations

This information is crucial to anticipate health problems, as well as to develop appropriate control measures

WILDLIFE CONSERVATION SOCIETY

www.wcs.org
www.fieldvet.org

Contact: pbeldomenico@wcs.org

# Is biodiversity a risk for disease emergence?

Richness positively correlated with disease emergence (Jones 2008)

**Table 1 | Socio-economic, environmental and ecological correlates of EID events**

| Pathogen type | Zoonotic: wildlife | |
|---|---|---|
| Number of EID event grid cells | 147–156 | |
| | *b* | *B* |
| log(JID articles) | 0.34-0.37*** | 1.41–1.45 |
| log[human pop. density (persons per $km^2$)] | 0.56–0.64*** | 1.75–1.90 |
| Human pop. growth (change in persons per $km^2$,1990–2000)† | 0.09–0.45 | 1.09–1.56 |
| Latitude (decimal degrees) | 0.002–0.017 | 1.00–1.02 |
| Rainfall (mm) | $(0.14–0.06) \times 10^{-3}$ | 1.00–1.00 |
| Wildlife host richness | 0.008–0.013** | 1.01–1.01 |
| Constant | −9.81 to −8.78*** | |

# Richness vs. EIDs

Is encroachment into wild habitats a confounder in their analysis?

# Hazard vs. Risk

A great biodiversity supposes also high pathogen diversity, and hence greater hazard, but this does not necessarily imply greater risk