Predicting the effects of climate change on infectious diseases of animals

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“We must understand how climate affects infectious diseases today before we can predict climate change’s impacts of the future”

UK Government Foresight Project 2006: Detection and Identification of Infectious Diseases; Future Threats, Appendix A

Climate affects:

- pathogens
- hosts
- disease-vectors
- epidemiological dynamics

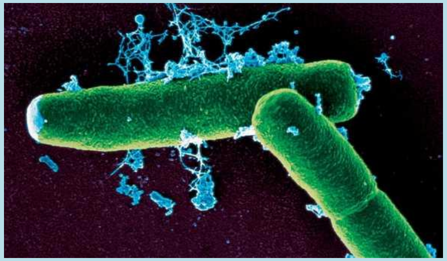
Climate and pathogens

- In order to get from one host to another, many pathogens spend time in the environment, exposed to the weather.
- Climate affects pathogen survival, generation times, and seasonality

Soybean leaf rust

hookworm

anthrax



Climate and hosts

- Temperature affects rates of plant growth and development; as temperature changes, so plants' ability to outstrip their pathogens may increase or decrease.
- Some plants lose their resistance to certain pathogens above threshold temperatures.

Wheat with root rot fungus

oats with stem rust

Climate and vectors

Climate plays a dominant role in determining where and when arthropod and molluscan disease vectors occur.

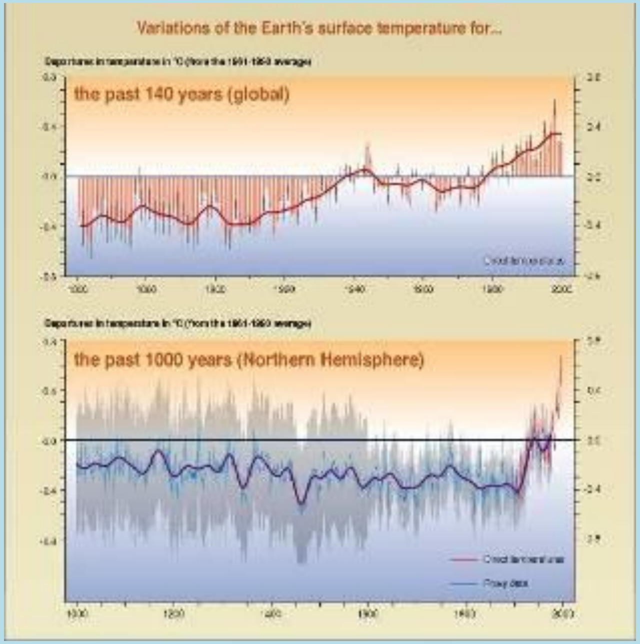
	Plants	Humans	Animals
Aphids, hoppers	Mosaic viruses		
Mosquitoes		MANY	West Nile fever, Rift Valley Fever
Midges			Bluetongue
Tsetse flies		Sleeping sickness	Animal trypanosomiasis
Ticks		MANY	MANY
Snails		Bilharzia	Fascioliasis

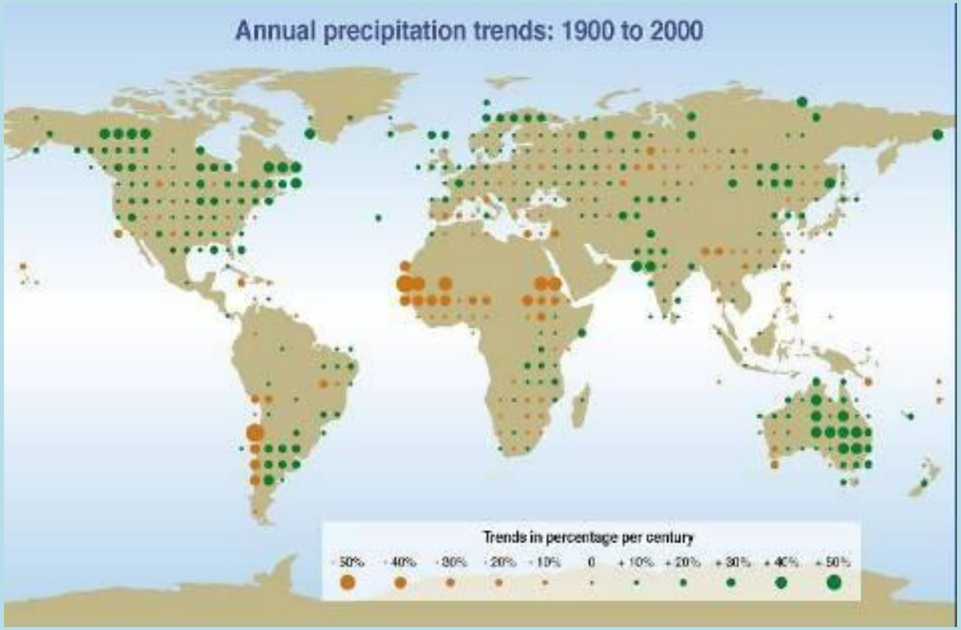
Climate and epidemiological dynamics

Climate can affect

- Transmission rates
- Contact networks
- Dispersal/migration rates or routes
- Landscapes
- Community structures
- Animal husbandry

What aspects of climate change will affect infectious diseases?





Temperature increase

Change to precipitation

Also: changes to humidity, soil moisture, winds, and increases inter-annual variability.

Significant challenges

The variables that we use in disease models are (probably) not those that really matter to diseases and vectors

The variables that we use in climate change models are (probably) not those that really matter to diseases and vectors – nor are they those that we use in disease models

The spatial scale of climate change predictions differs from that of disease models

How to incorporate change in climate variability?

Which diseases will be most (rapidly) affected?

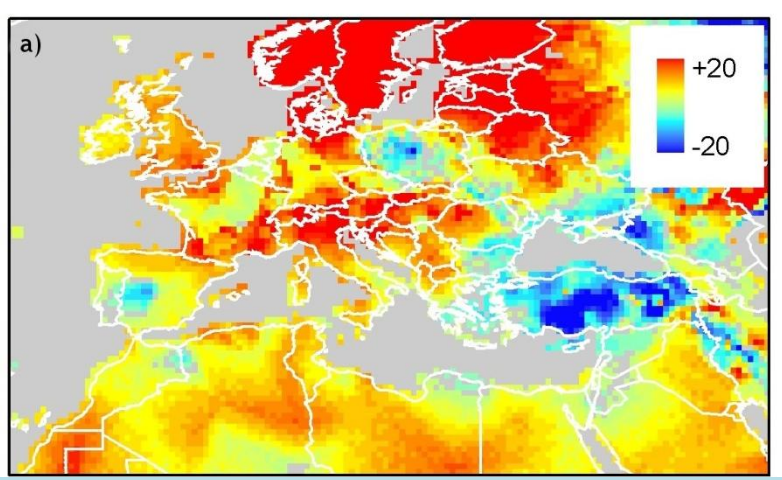
Climate change's effects will be most pronounced on diseases whose pathogens spend considerable time outside of the host:

- Free-living stages of parasites
- Vector-borne diseases
- Water-borne diseases
- Spore-forming pathogens

Evidence for climate change's influence on infectious disease: the case of bluetongue

Culicoides biting midge

European temperature change: 1980s v 1990s



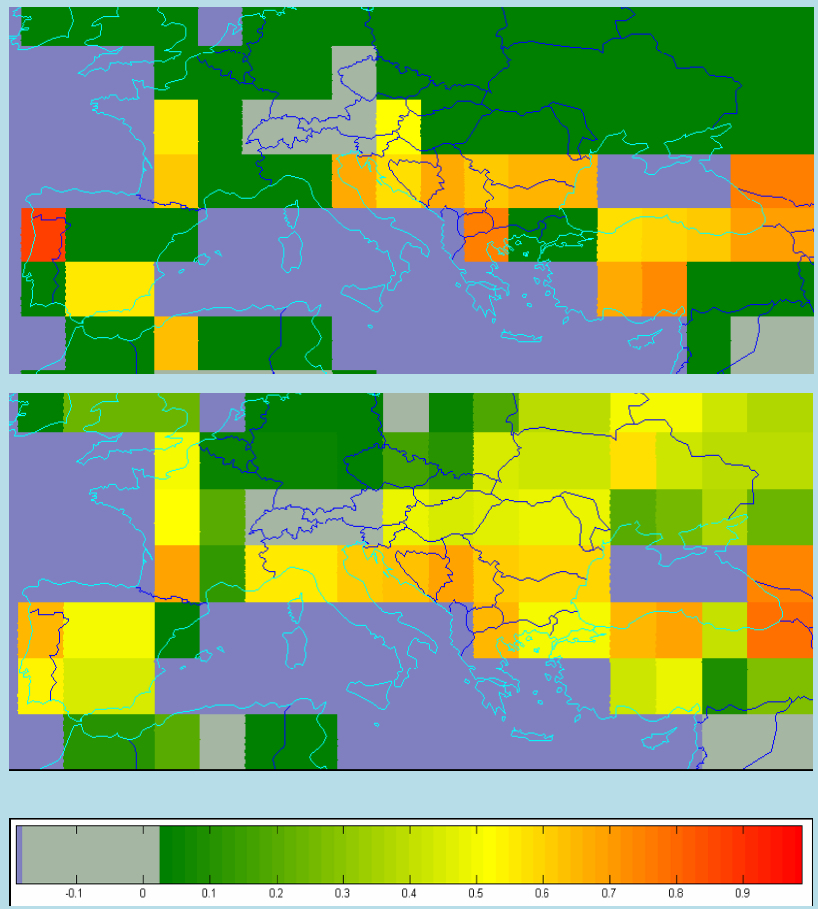
"The spread of bluetongue and its vectors presents some of the strongest evidence to date that climate change is driving vector-borne diseases into new regions, as warming and disease spread have occurred at the same times in the same places"

(2006, Future Threats, Appendix A)

An attempt to predict the future: bluetongue in UK

2015

2030



index of suitability for BT transmission

Source: Beth Purse *et al*. Modelling review T8.3, 2006

BT in the UK in 2007!

22 September: BTV serotype 8 confirmed on a single farm near Ipswich

64 cases by end-November2007

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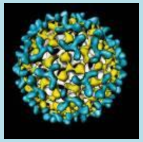
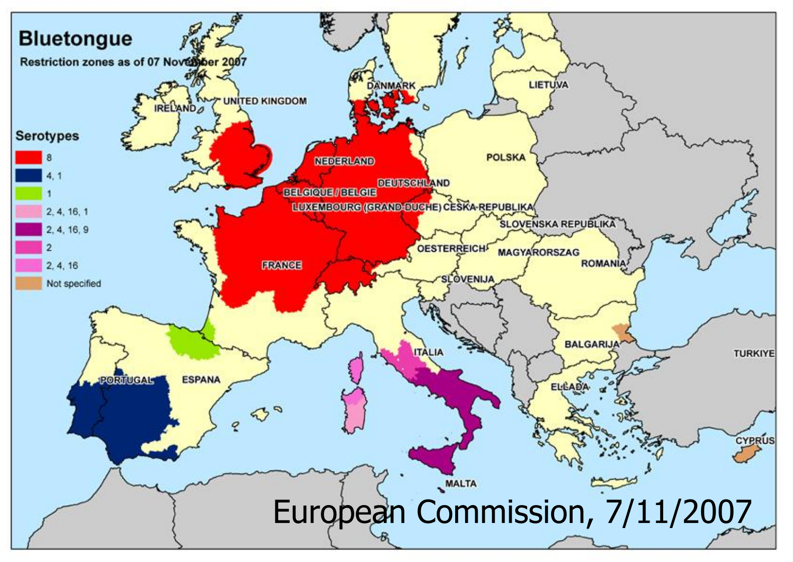
- Research Leadership Award by Leverhulme Trust for 4 years.
- Creates a new group at Liverpool University, called LUCINDA (*Liverpool University Climate and Infectious Diseases of Animals)*, sited in the Vet Faculty at Leahurst.
- Comprising:
  - Post-docs x 4
  - PhD students x 2
  - Technical assistance
  - Secretarial assistance

Bluetongue: vector-borne disease of ruminants transmitted by biting midges *(Culicoides)*

Hosts  Ruminants

Vectors  *Culicoides*

Virus  *Orbivirus*



Context: major expansion throughout the Mediterranean Basin in the last 10 years and emergence in northern Europe in 2006.

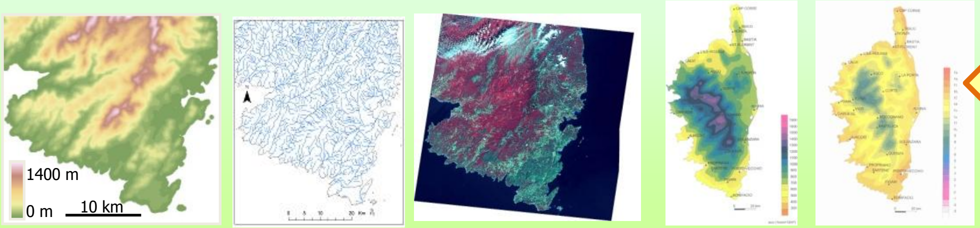
Project: Better understanding of the environmental conditions (landscape + climate) favourable to bluetongue vectors → identify which areas are at risk and at what time

Tools: Remote sensing data + Geographic information systems (GIS)

• Different remote sensing images → characterize the environment: vegetation, altitude, hydrology, climate

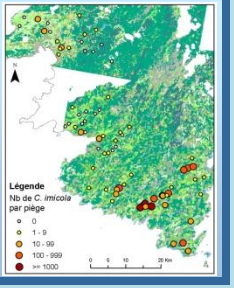
• GIS: spatially link environmental conditions to the vector distribution

Environmental data



Entomological data

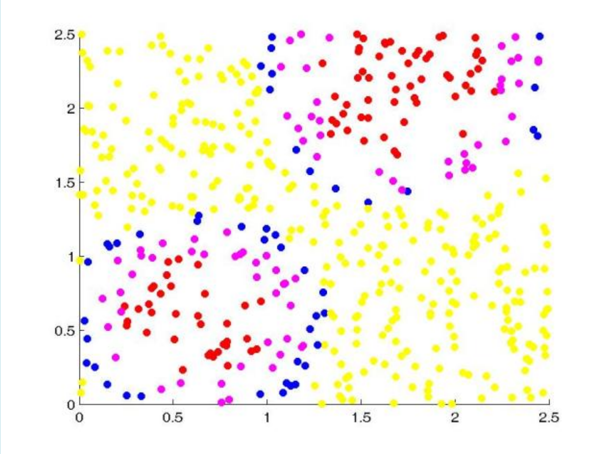
Trapping campaigns: vector abundance



Bluetongue modelling – Joanne Turner

- Aim: To build a mathematical model that describes the spread of bluetongue between farms in UK.
- Infection is spread by:
  - movement of exposed and infected animals;
  - diffusion of infected vectors.
- Changes in temperature, rainfall, etc. can affect:
  - vector population (e.g. population size, ability to overwinter);
  - virus multiplication within the vector.
- Further work:
  - The effects of climate change (in particular temperature) on the within-farm dynamics of bluetongue.
  - The effects of climate change on other animal diseases of economic importance.

Restriction zones around infected premises

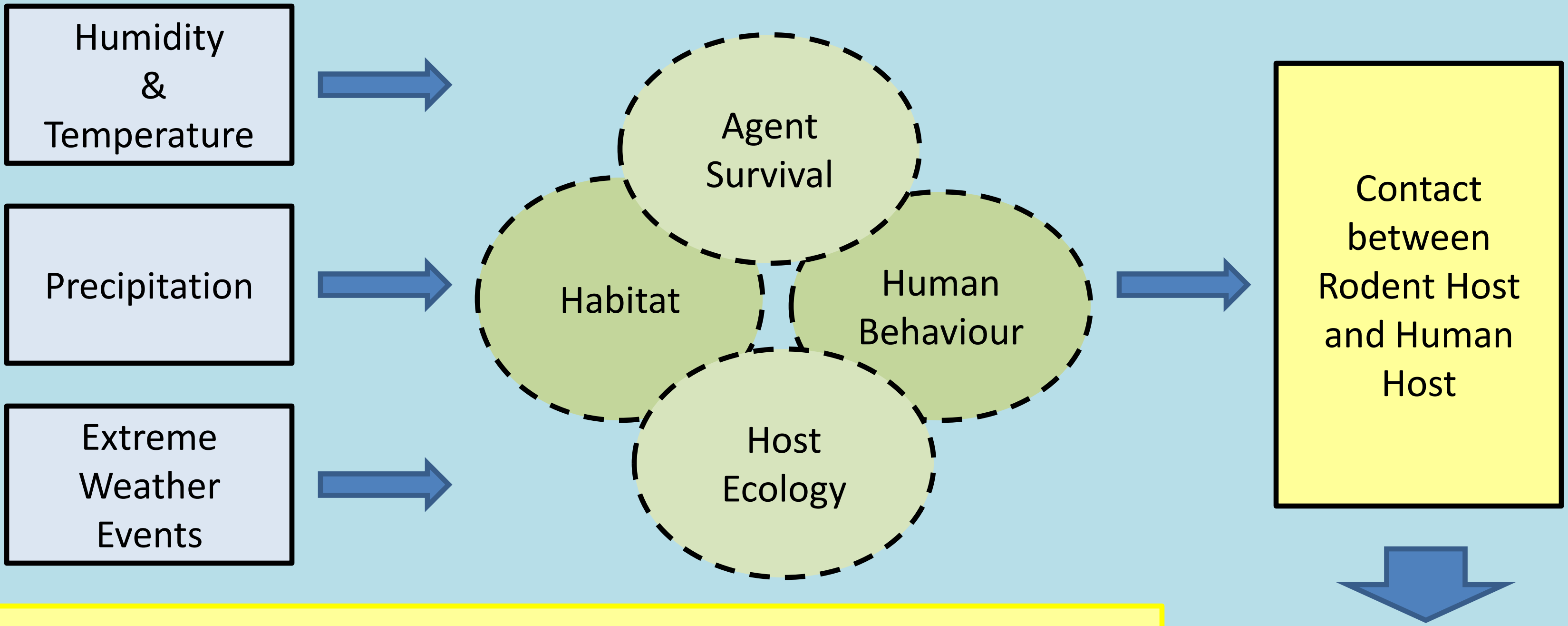


Japanese encephalitis – Daniel Impoinvil

- Japanese encephalitis virus is a major cause of encephalitis in Asia, killing 10-15,000 people annually.
- It occurs epidemically in northern temperate regions, and endemically in southern tropical regions.
- How will climate change affect these dynamics?

Culex tritaeniorhynchus

Climate Effects on Plague Incidence in Africa – Kathy Kreppel (PhD)

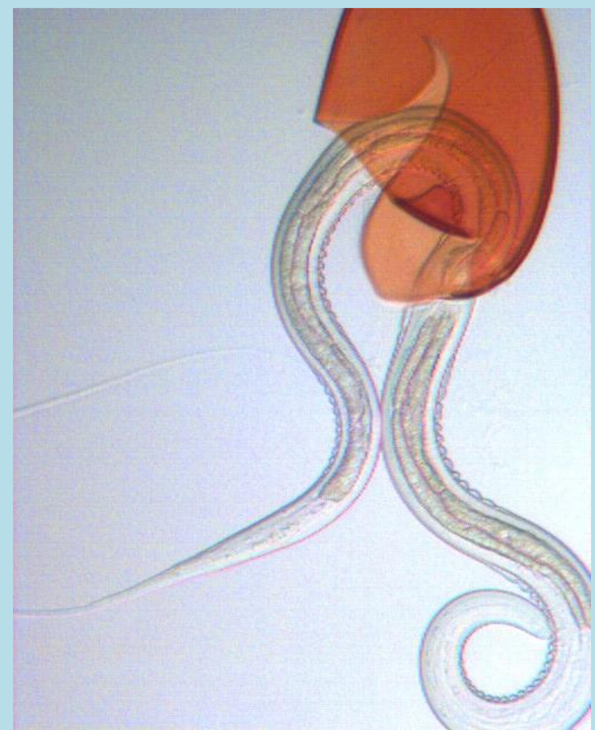


- **Identification of climate variables determining the spatial distribution and incidence of plague**
- **Development of a forecasting model to predict plague outbreaks**
- **Predictive model for effects of climate change on plague incidence in Africa**

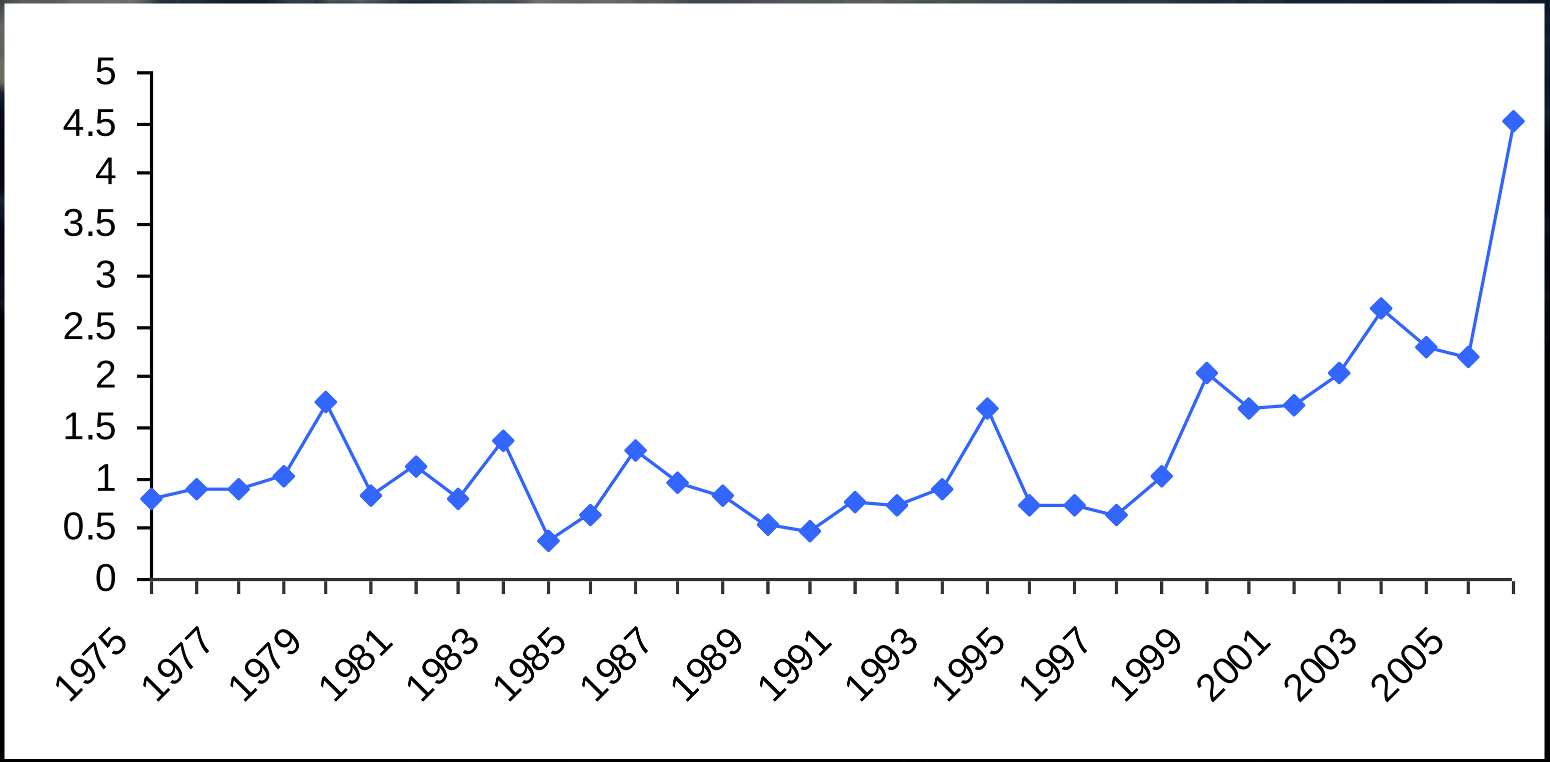
Host-parasite interactions

Jan van Dijk

Helminths



Cases of nematodirosis recorded by veterinary surveillance laboratories in GB, 1975-2006, expressed as a percentage of the total number of submissions.



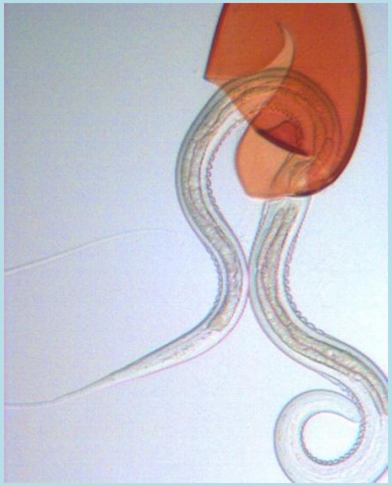
$r_s = 0.450$, $p = 0.005$

$F_{5,29} = 49.2$, $p = 0.011$

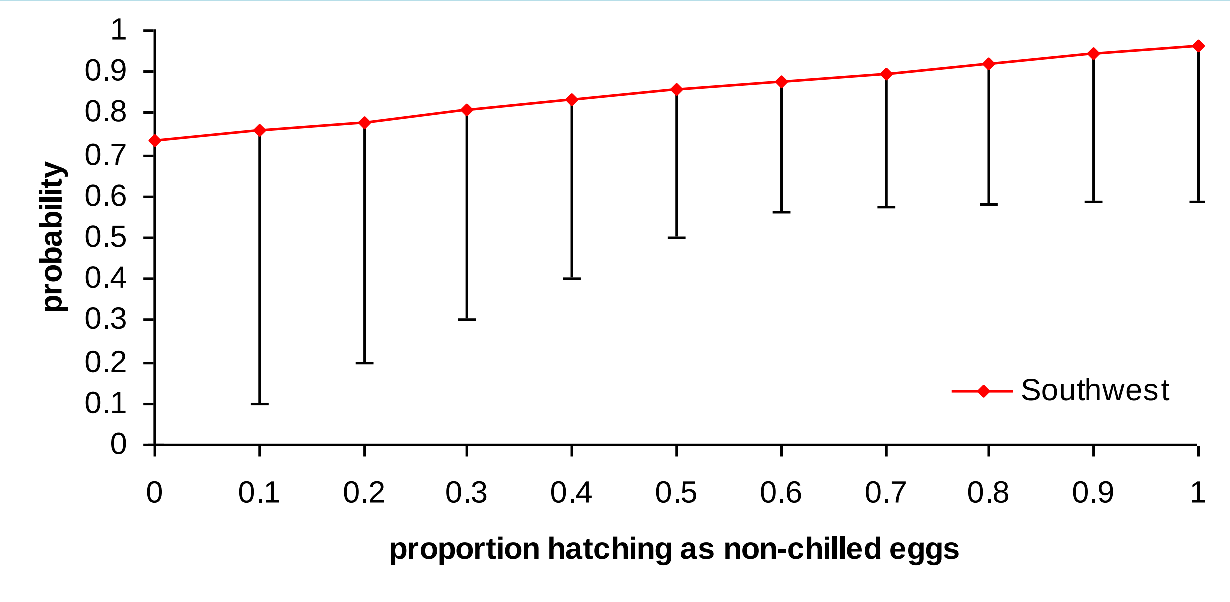
Parasite evolution

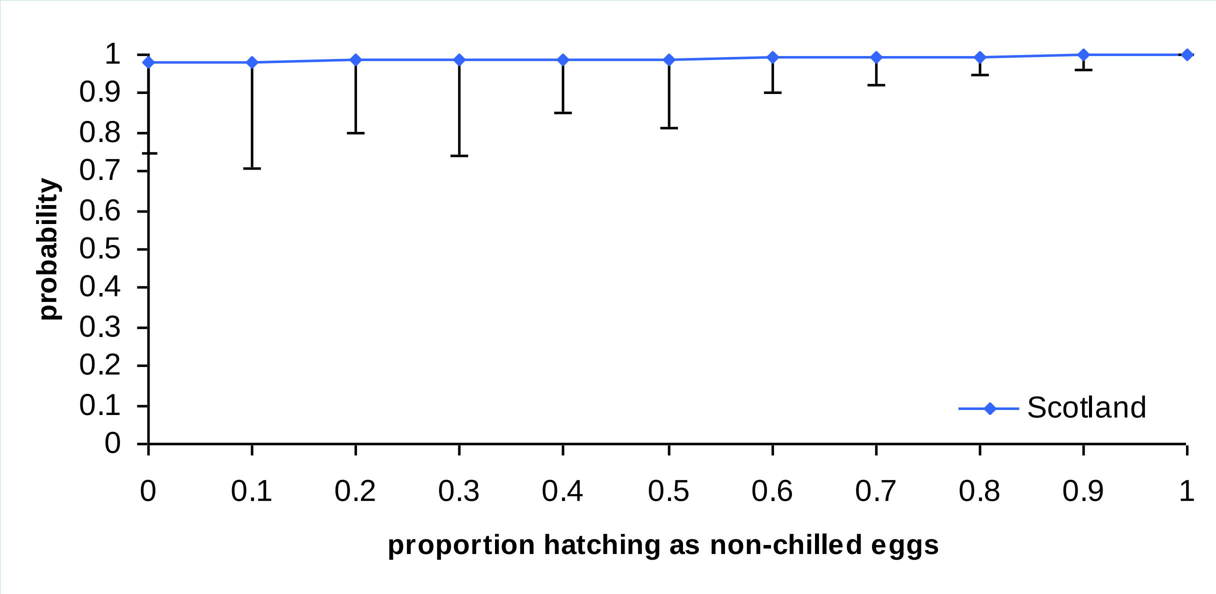
Bet-hedging

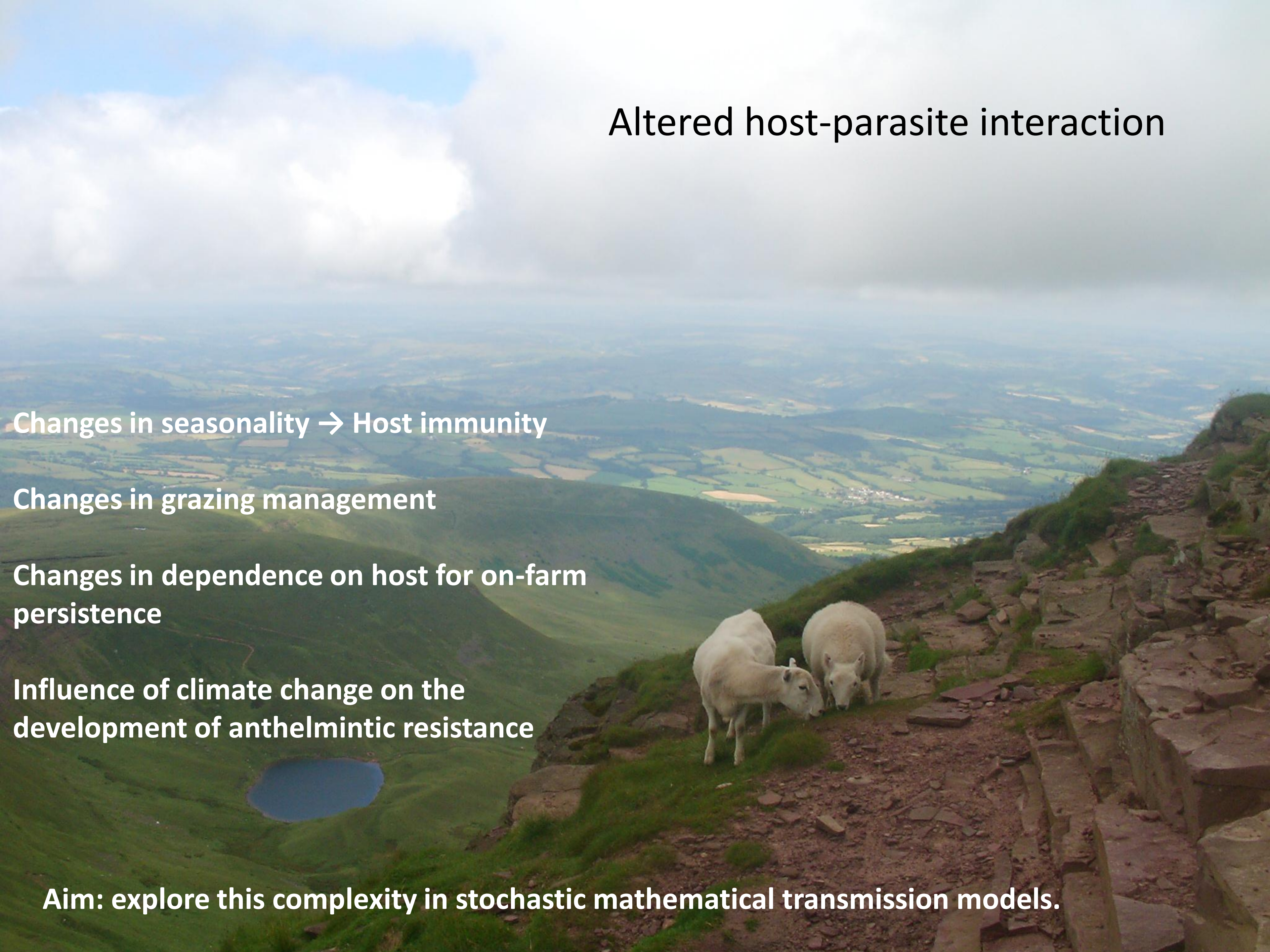
and the probability of hatching within one year



Error bars represent the lower 95% confidence bounds







Altered host-parasite interaction

Changes in seasonality → Host immunity

Changes in grazing management

Changes in dependence on host for on-farm persistence

Influence of climate change on the development of anthelmintic resistance

Aim: explore this complexity in stochastic mathematical transmission models.

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