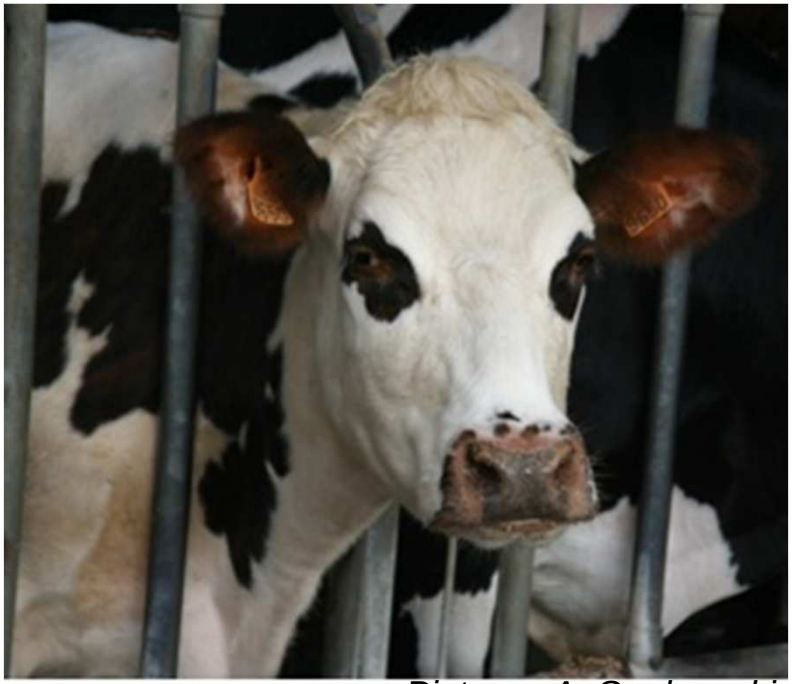
Assessment by modeling of the effectiveness of vaccination against Q Fever in dairy cattle



Picture : A. Senkowski

Aurélie Courcoul
Lenny Hogerwerf
Don Klinkenberg
Mirjam Nielen
Elisabeta Vergu
François Beaudeau

Oniris
École Nationale Vétérinaire, Agroalimentaire et de l'Alimentation
Nantes Atlantique

INRA

Q Fever: a public health issue (1)

Zoonosis due to Coxiella burnetii

Humans

Often asymptomatic

Flu-like illness, pneumonia, hepatitis, endocarditis, abortions

Ruminants

Asymptomatic or reproduction disorders:

abortions, infertility, metritis

Human epidemics in several parts of Europe (e.g. Netherlands 2007-2009)

Q Fever: a public health issue (2)

Ruminants = main sources of human infections

Bacteria shed by infected animals **through various routes**

Bacteria with **high resistance in the environment**

Contamination mainly by **inhalation of infected aerosols**

Control of ruminants infections:
main factor to control human outbreaks

Q Fever: a public health issue (3)

Little information available on the effectiveness of control strategies in ruminants

Vaccination : seems an efficient tool

in goats: strong reduction of abortions and frequency of shedding (***Arricau-Bouvery et al. 2005***)

in cattle: when vaccinated when S and non pregnant: 5 times lower probability of becoming a shedder (***Guatteo et al. 2008***)

Experimental conditions or limited period of time

Difficult to extrapolate those results to a whole herd vaccinated over several years

Objective

Assessment of the effectiveness of vaccination in dairy cattle herds

✓ ***To build a model representing the spread of C. burnetii within a dairy cattle herd***

✓ ***To represent the infection control strategies and to compare them by simulation*** ***(impact on clinical signs, prevalence of infection and contamination of the environment)***

Picture : A. Senkowski

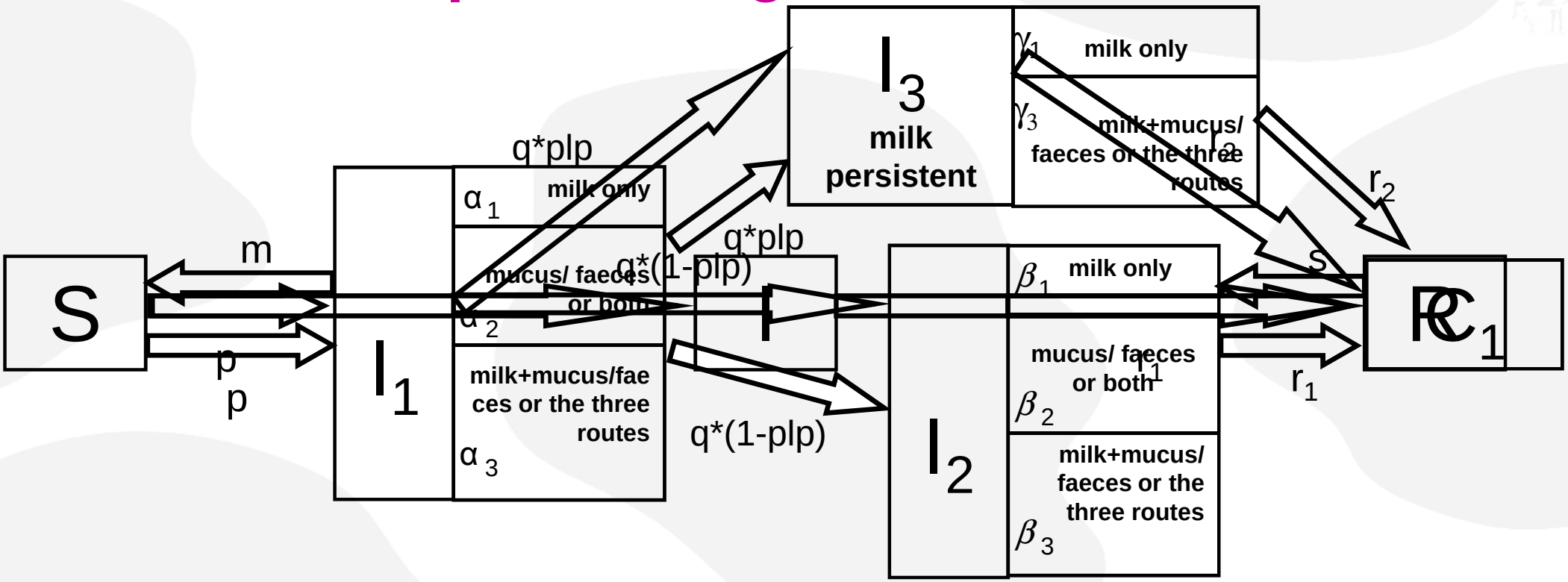
Model assumptions

Typical epidemiological model = SIR model

But* C. burnetii *spread is a complex process

- ✓ ***Different types of shedders: some shedders can eliminate the bacterium, others are chronically infected***
- ✓ ***Different shedding routes and levels***
- ✓ ***Intermittent shedding***
- ✓ ***Natural immunity with a limited duration***
- ✓ ***Probability of infection linked to the environmental bacterial load***

Epidemiological model

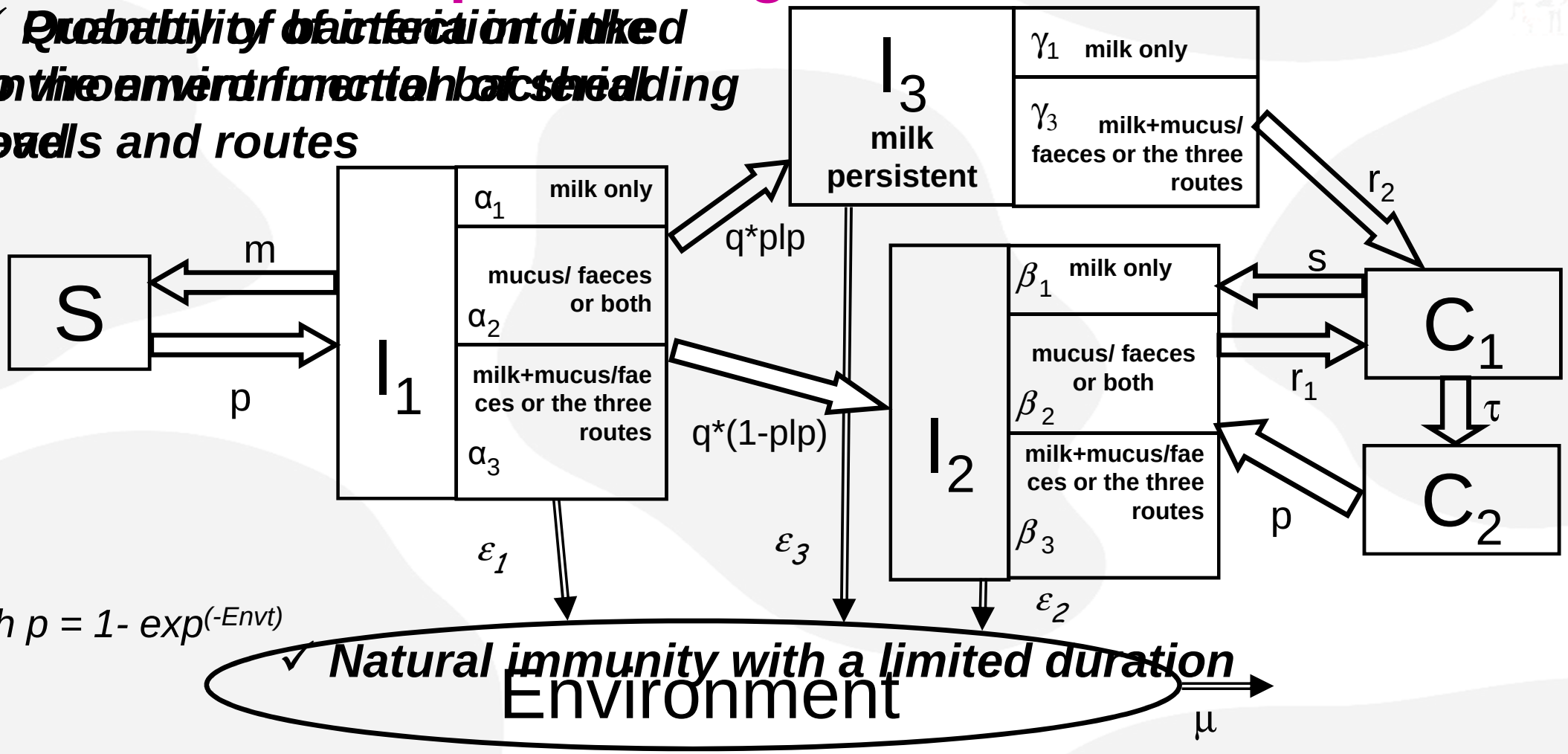


- ✓ ***Different types of shedders***
- ✓ ***Some shedders can eliminate the bacterium***
- ✓ ***Different shedding routes***
- ✓ ***Intermittent shedding***

Epidemiological model

✓ *Probability of infection linked to the environmental bacterial load*

✓ *Probability of infection linked to the environmental bacterial load and routes*



with p = 1- exp(-Envt)

✓ ***Natural immunity with a limited duration***

Epidemiological model and population dynamics

Individual-based stochastic model

in discrete time (time step of a week)

Epidemiological model coupled with a model of herd demography:

- ***stage of lactation***
- ***stage of gestation***
- ***lactation number***
- ***health state towards* C. burnetii *infection***
- ***shedding route***
- ***quantity of bacteria shed through each route***
- ***abortions attributable to Q fever***
- ***culling***

Representation of vaccination

Assumptions & initial conditions:

A. Phase 1 vaccine effective when applied on non pregnant S or C_2 animals (Guatteo et al. 2008)

1- p_v = 0.21*p *(transition S => I_1 or C_1=>I_2)*

2- decreased quantity of bacteria shed

3- no abortion

No change for pregnant S, I and C_1 animals

B. Vaccination programmes start after the 3rd abortion in the last 12 months within a herd

Assessment of the comparative effectiveness of vaccination strategies

3 scenarii

1. **Both cows and heifers vaccinated for 10 years**
2. **Both cows and heifers vaccinated for 3 years**

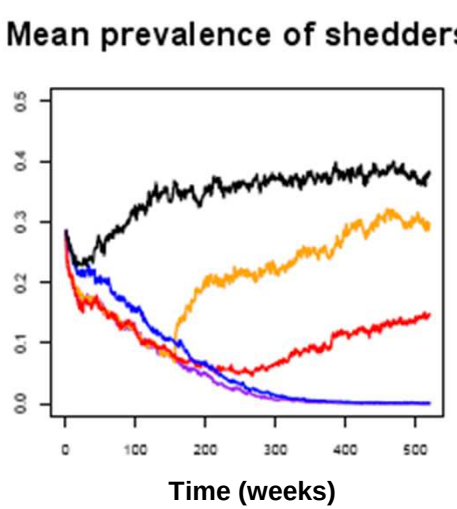
   with or without loss of immunity at the end of the programme (2A and 2B)
3. **Heifers only at the beginning of the programme, then booster doses for both cows and heifers for 10 years**

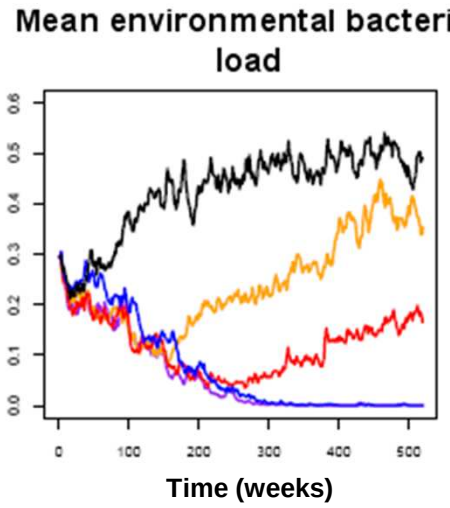
Criteria of effectiveness

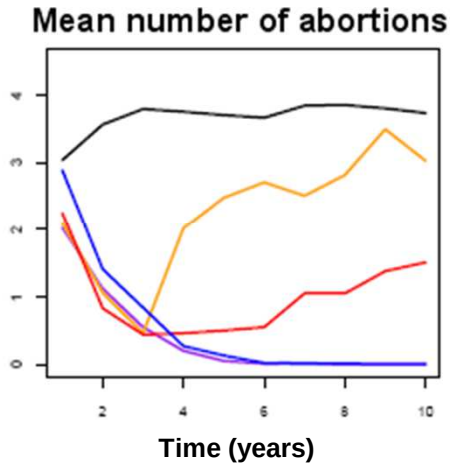
Decrease in

- ✓ **the clinical signs (abortions)**
- ✓ **the prevalence of infected animals**
- ✓ **the environmental bacterial load (zoonotic risk)**

Results (1)







Legend for (a), (b), and (c)

- Scenario 1 (Heifers & Cows - 10 years)
- Scenario 2A (H&C -3 years -one-year immunity)
- Scenario 2B (H&C -3 years -lifelong immunity)
- Scenario 3 (at t0, H only then H&C - 10 years)
- Control (no vaccination)

Vaccination effective to decrease the outputs

BUT

Ineffective on the long run when too short vaccination period

Results (2)

Extinction probability (*neither I nor C_1 individuals)*

Criteria	Scenario				
	Control	1	2A	2B	3
Extinction	+	++++	+	++	+++

Mean time to extinction

For scenario 1: week 290

Before stopping vaccination, useful to determine the presence/absence of *C. burnetii*

Conclusion

Comparison of the effectiveness of 3 vaccination strategies

effective but not equivalent strategies on the long run

This work can guide farmers and decision makers in the design of control programmes for Q fever in cattle

Work in progress:

adaptation of this model to dairy goats in the Netherlands

Thank you for your attention !