The estimation of age-stratified rates of infection for bovine tuberculosis in Ireland

Jamie M. Madden[1], Miriam Casey-Bryars[1], Ellen Brook-Pollock[2], Simon J. More[1]

[1]Centre for Veterinary Epidemiology and Risk Analysis (CVERA), University College Dublin, Dublin, Ireland
[2] Bristol Medical School, University of Bristol, England

Introduction and aims

Bovine tuberculosis (bTB), caused by infection with *Mycobacterium bovis,* is endemic in cattle in many countries including Ireland. Significant advances have been made in Ireland since the introduction of a bTB eradication programme which began in the 1950s but further progress towards bTB eradication, and an officially bTB (OTF) free status for Ireland, is proving to be particularly challenging with annual herd-level incidence varying between approximately 3-5% over recent years. bTB in Ireland is a complex disease of cattle and can infect many species, including wildlife, particularly badgers. As such, researchers and policy makers are continually looking for novel bTB research avenues that may provide new insights into the disease for Ireland. Here, we explore age-specific reactor rates with a view to estimating the force of infection (FOI), a key infectious disease parameter which represents the rate at which susceptible subjects acquire an infectious disease. Knowledge of this parameter and how it varies between different groups and over time can provide new insights and understanding as to how an infection spreads in a population. It can also be used to help planning, optimizing management interventions (via modelling simulation scenarios) and used to obtain an estimate of the basic reproduction ratio of a disease (R_0). Given information about FOI in a population, interventions can be targeted to those at the most significant risk of infection. We outline initial findings here, focusing on bTB.

Methods and preliminary results

In this initial work, the study cohort included all animals that were bTB tested (or slaughterhouse inspected) during 2015 (extending to 2023 in future work). For this work, a diagnosis of bTB included all single intradermal comparative tuberculin test (SICTT) reactors, and/or a positive IFN-γ test result. We estimated the reactor rate (number of bTB cases as numerator and the number of animals tested as the denominator) in different age classes.

During 2015, there were 6,768,402 unique animals that had at least one SICTT performed (some would naturally have had more than one test conducted if they were part of an ongoing herd breakdown). Of these, 15,227 (0.22%) animals were classified as bTB positive using the SICTT/IFN-γ.

Remaining work will focus on FOI, $\lambda(t)$, which depends on the effective contact rate (per unit of time) (β) and the number of infectious individuals (I) at time t, i.e., $\lambda(t) = \beta I(t)$. Classical methods for estimating the FOI are based on the fact that the proportion of individuals who have ever been infected increases with age as a result of increased time of exposure to the infection. Such a model, known as a `catalytic model`, initially proposed by Muench (1934, 1959) for modeling prevalence is given by $\pi(a_i) = 1 - e^{-\lambda a_i}$ where a_i is the probability to be infected before age a_i. The assumption made here is that FOI is constant over time which may not be true for all diseases. Minor changes can be made to the model to overcome this issue (e.g., piecewise catalytic model etc.) which will be explored in future work.

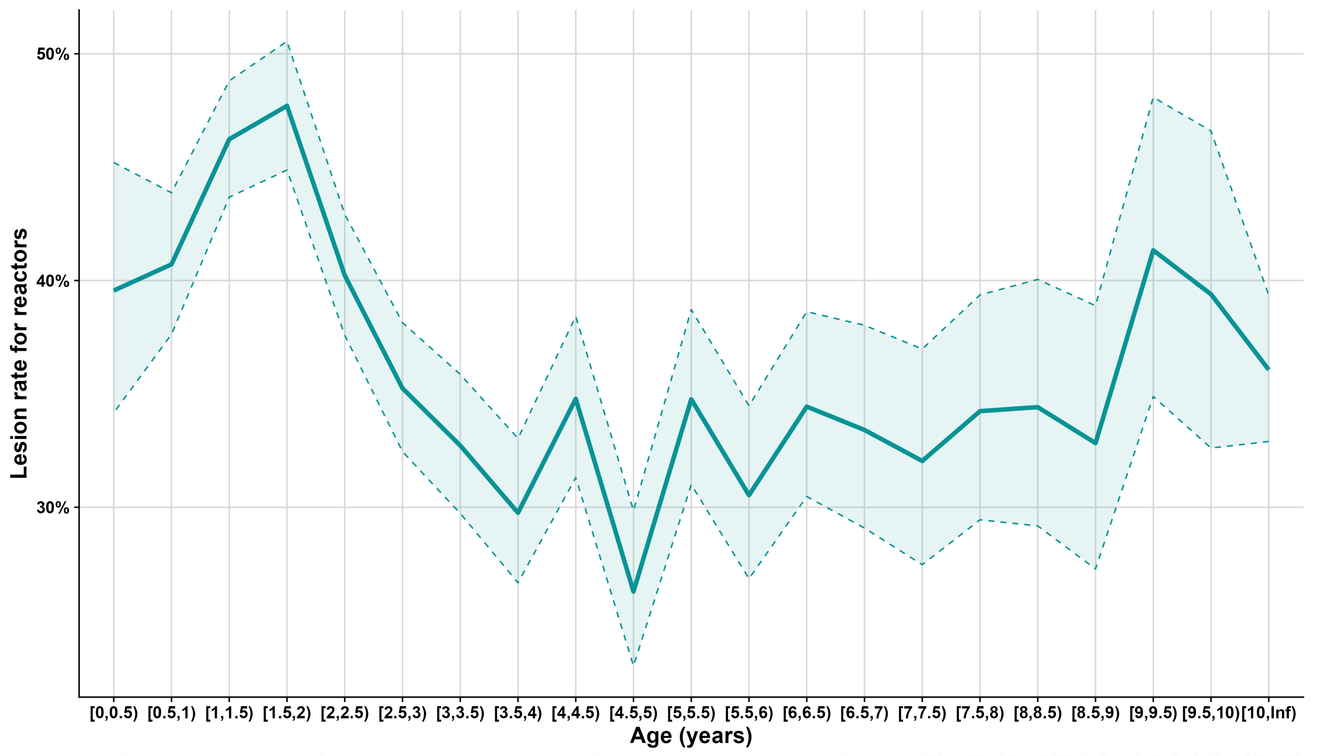

Figure 2: Age-specific lesion rates (with 95% CI) for bovines classified as bTB positive animals (based on SICTT/IFN-γ) during 2015.

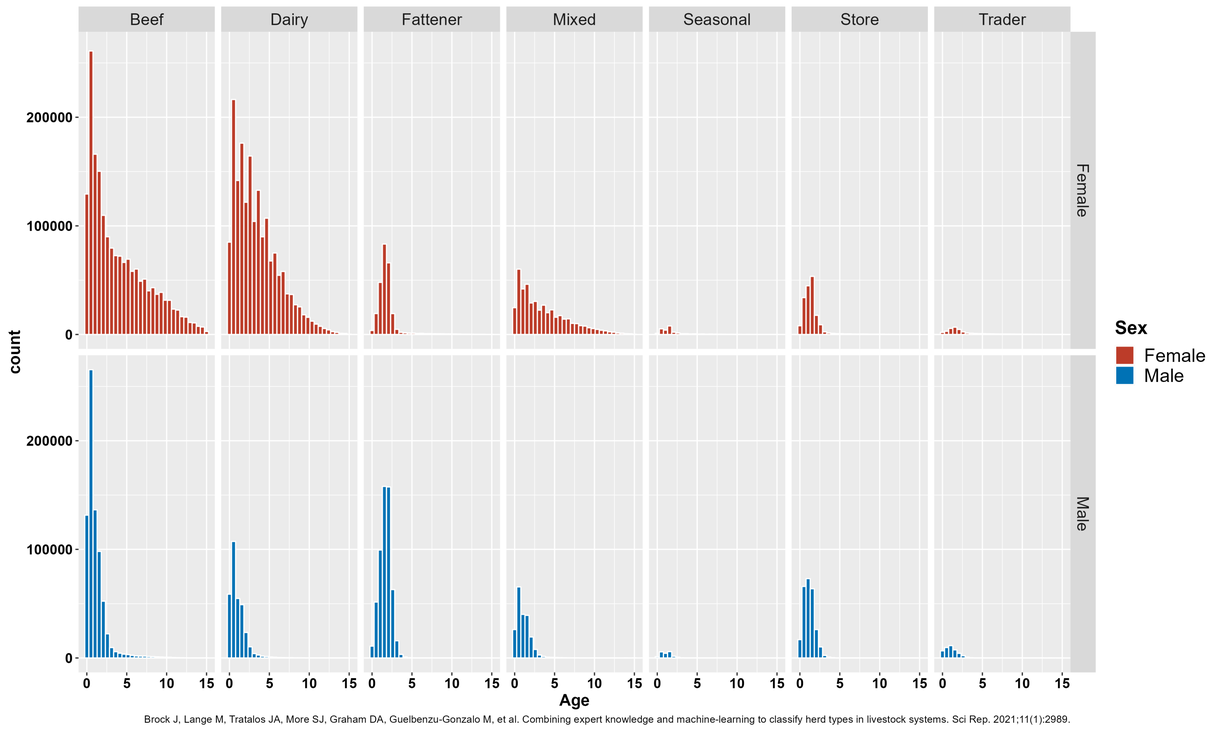

Figure 1: Histogram (count) of the age distribution of bovine animals in 2015 from Ireland by herd type and sex.

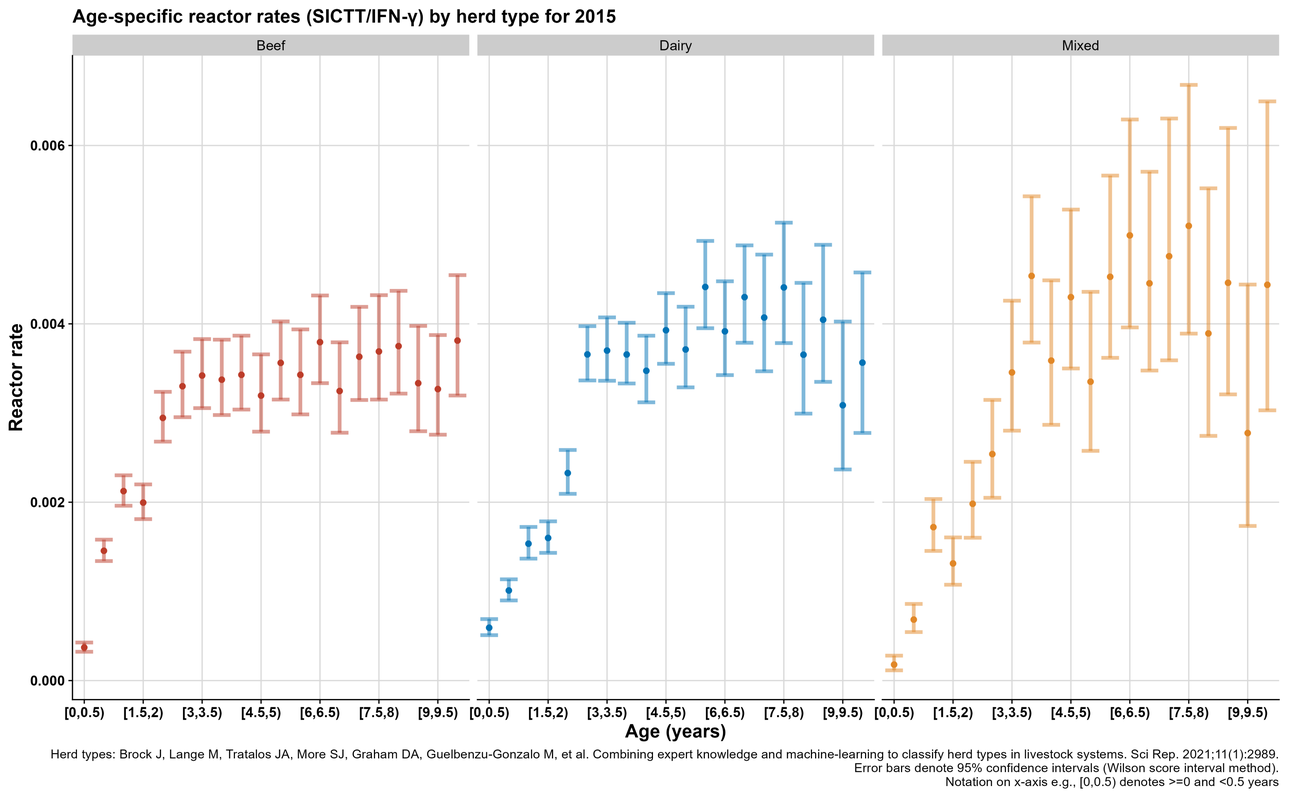

Figure 3: Age-specific reactor rates for 2015 as classified by the SICTT/IFN-γ.

Conclusions to-date

In this initial work, we found that for animals from all herd types, the bTB reactor rate increased steadily from birth until approximately age 3-4 years. Generally, it began to plateau from this age onwards. Given the age structure of the national herd, the average age of infection is likely to be young, and as the probability of detecting the infection with the SICTT is biased towards the younger animal, this is where you are likely to see the higher lesion rates too. Remaining work in this area will focus on estimating FOI and explore how this has changed over time.