Insights for brucellosis eradication in Italy through a model-based spread evaluation in grazing livestock - Sicily case study

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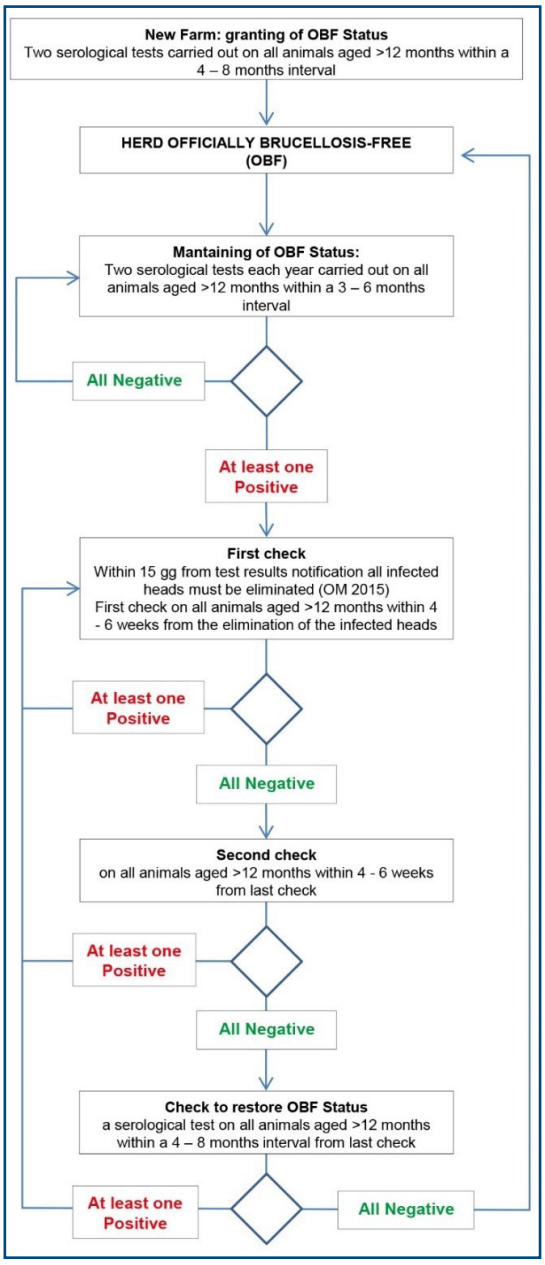
S1 – Italian national eradication program for bovine brucellosis

A summary of the actions to be taken in the context of the Italian National Eradication Program for bovine brucellosis is shown in **S1 Figure**.



S1 Figure. Italian National Eradication Program for bovine brucellosis. *Summary of the actions to be taken in the context of the Italian National Eradication Program for bovine brucellosi.*

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S2 – Italian national eradication program for bovine brucellosis

The Simulator was implemented and analysed using the R software.

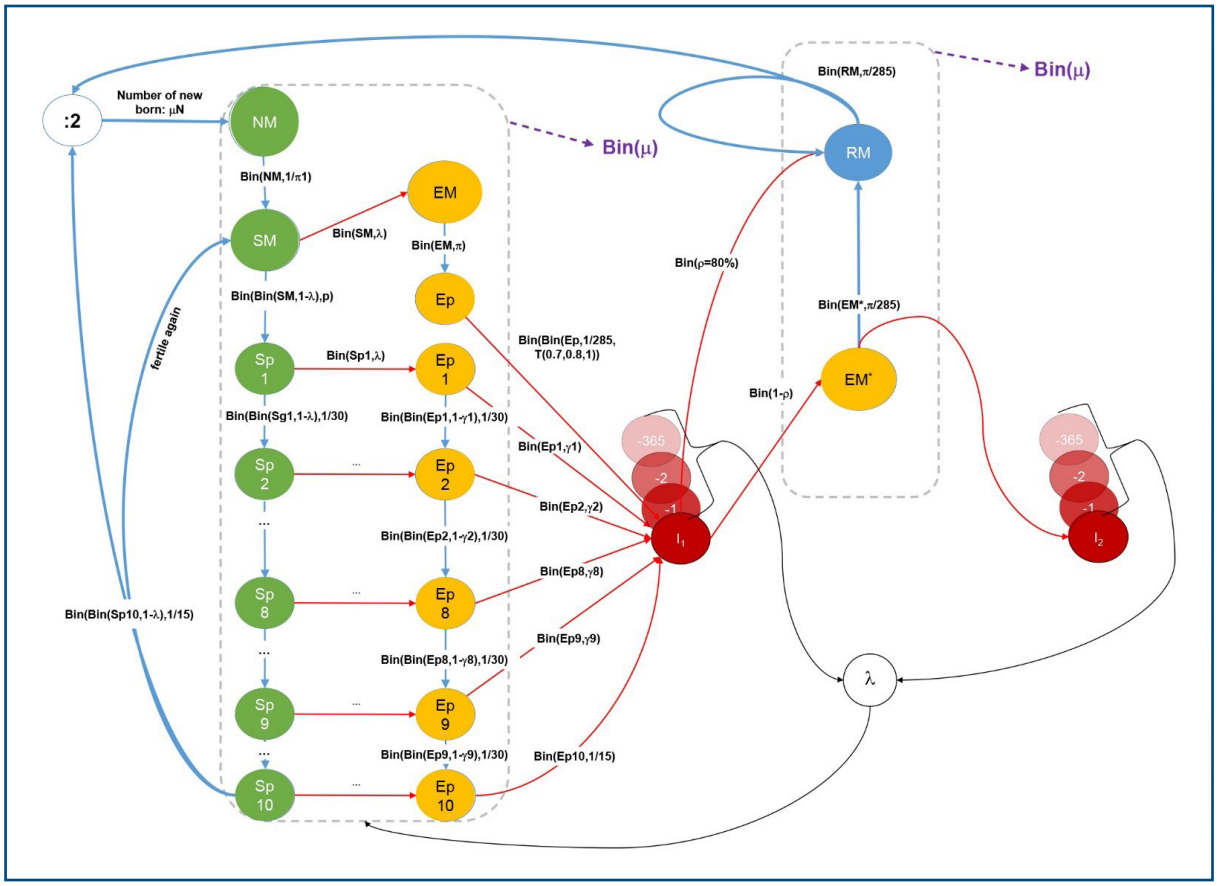
S2A - SEIR model flow description

A detailed description of SEIR compartmental model flows among each demographic categories of epidemiological interest is shown in **S2A Figure**. Infection events are linked to places rather than infectious animals and thus, they are shared between herds during the pasture period.

The Exposed cows will produce infectious events at the first abortion (I1) and with a probability of 20% at the following parturition (I2). It is assumed exposed cows turn in recovered or back to exposed as soon as they abort. For this reason, the I compartment doesn't represent infectious animals but infectious events (*Brucella* shed following the abortion).

The figure shows the demographic categories (d) to highlight and distinguish the flows determined by the SEIR model (horizontally) and those determined by time (vertically) on the demographic categories. New-born cows become sexually mature with an average time π1=484 days.

The probability a sexually mature cow will be impregnated on a specific day is expressed by π, shifting 285 days back its probability of giving a birth on a specific day.



S2A Figure. SEIR model flow description. *Description of SEIR compartmental model flows among each demographic categories of epidemiological interest. The circle's colour represents the epidemiological state: green for healthy animals, yellow for exposed, and blue for recovered, whilst the circle's label identifies the demographic categories of epidemiological interest (not sexually mature (NM), sexually mature (M), pregnant per month (p1-p10), and pregnant without the need of discerning the month of pregnancy (p)) and the SEIR compartment (susceptible (S), exposed (E), recovered (R)). Please note: M* represents cows exposed because previously had aborted. They will surely abort at the following parturition, thus increasing the I2 compartment. It is assumed exposed cows turn in recovered or back to exposed as soon as they abort. For this reason, the I compartment doesn't represent infectious animals but infectious events (*Brucella *shed following the abortion). Statistical distribution functions have been abbreviated in Bin (binomial), and T (triangular).*

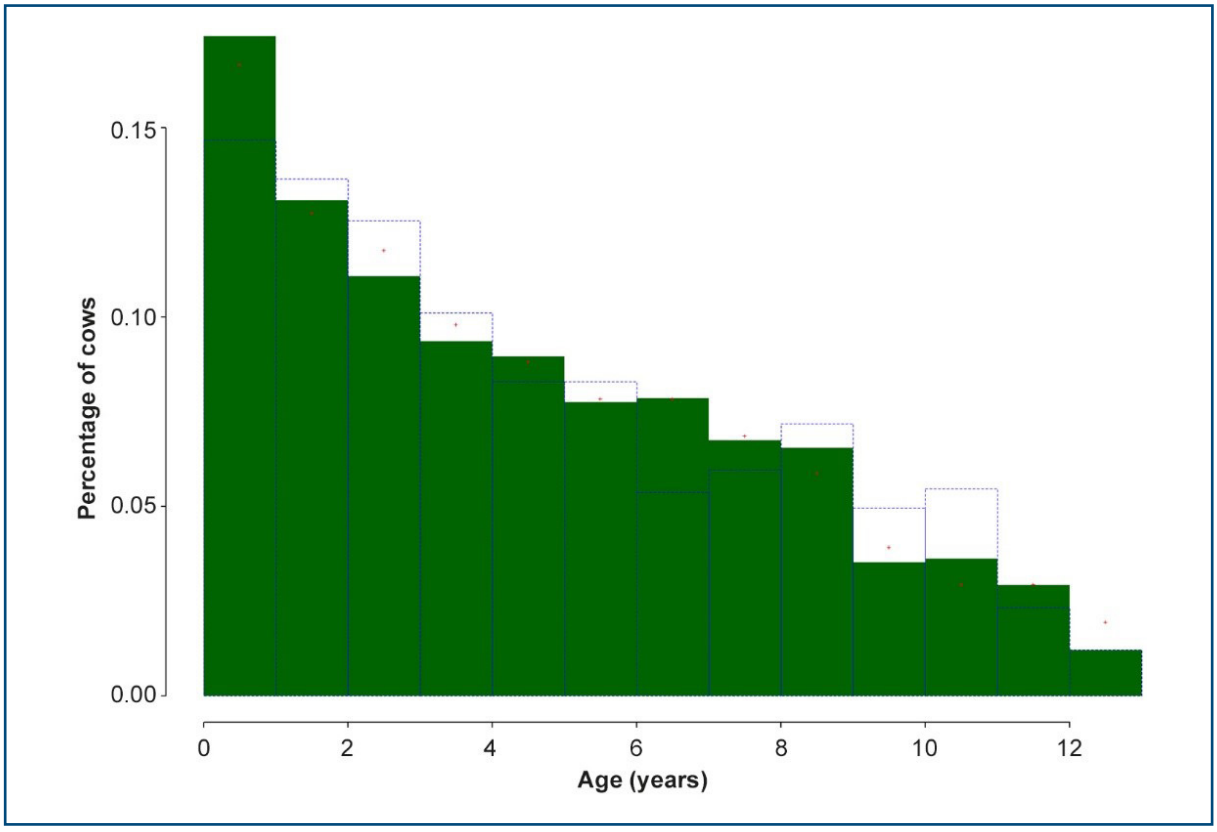
S2B - Simulator algorithm

(1) Generation of one pasture and the corresponding size of 5 herds;
(2) IBM model generate the demographic characteristics for each cow in each herd;
(3) exposed animals are identified for the SEIR initial state;
(4) the SEIR model executes the following step each day (for 8 years):
   - add new borne animals to the system;
   - let the disease spread;
   - if Tc > 0 & t=Tc, the control option model simulates the tests results;
   - remove the animals leaving the system due to turnover and to test results if t=Tc+Ta.
(5) go back to point 4 for 50 (Nsim) times;
(6) go back to point 1 for 20 (n) pastures.

S3 - IBM simulation results validation

S3A - Age classes distribution

The distribution of age classes at the first day of the year (green bars) and after 365 days (blue bars) of a population of N = 10.000 simulated and the theoretical distribution (red crosses) is shown in S3A Figure. The results show that the population distribution by age class of the simulated population has a distribution similar to the theoretical one deriving from the data provided by the NDB.



S3A Figure. Age classes distribution. *The distribution of age classes at the first day of the year (green bars) and after 365 days (blue bars) of a population of N = 10.000 simulated and the theoretical distribution (red crosses).*

S3B - The temporal trend of cattle population simulated

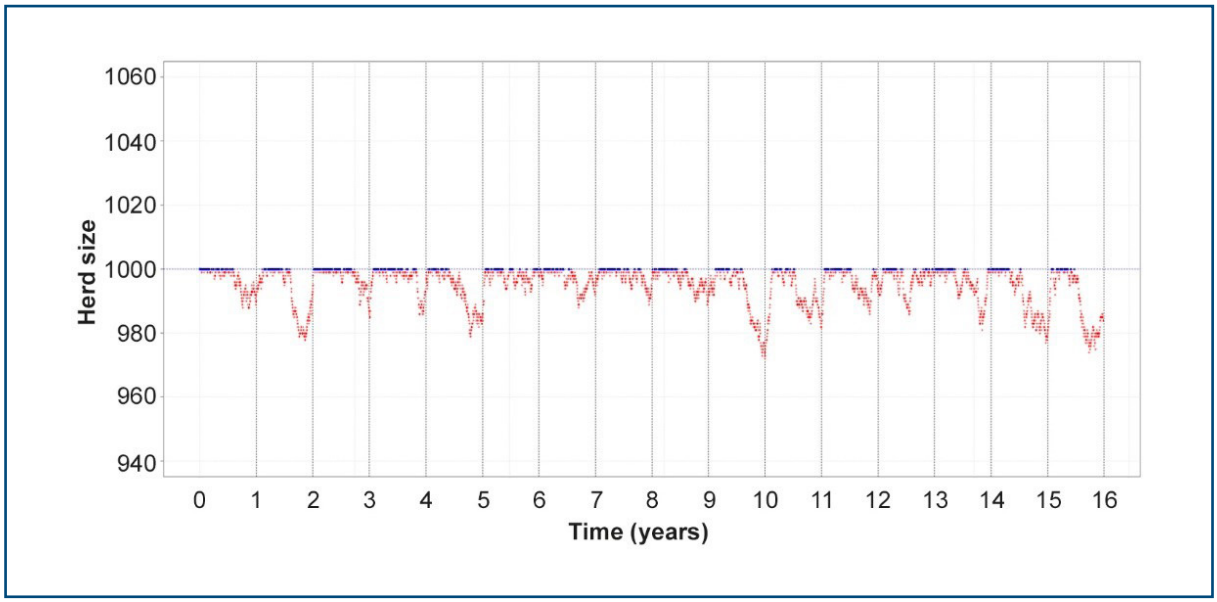
The Productivity level determines the availability of new-born during the year. Consequently, it also affects the ability to keep the population constant, given a turnover.

The incursion of the infection lowers productivity and consequently the ability to keep the population constant.

The animals leaving the system at each time step are replaced by the availability of female cows among those born (50%). For this reason, the population may be in deficit at times of the year when fewer births occur. This deficit will then be recovered in the periods of greatest birth rate.

S3B Figure shows how a population of 1.000 animals evolves over a 16-year period with a Turnover = 20% and Productivity = 65%.

The periods when the population decreases compared to the initial value are highlighted by red dots. The simulation highlights how the periods of population deficit are in correspondence with the periods of the year with the lowest birth rates (second half of the year).



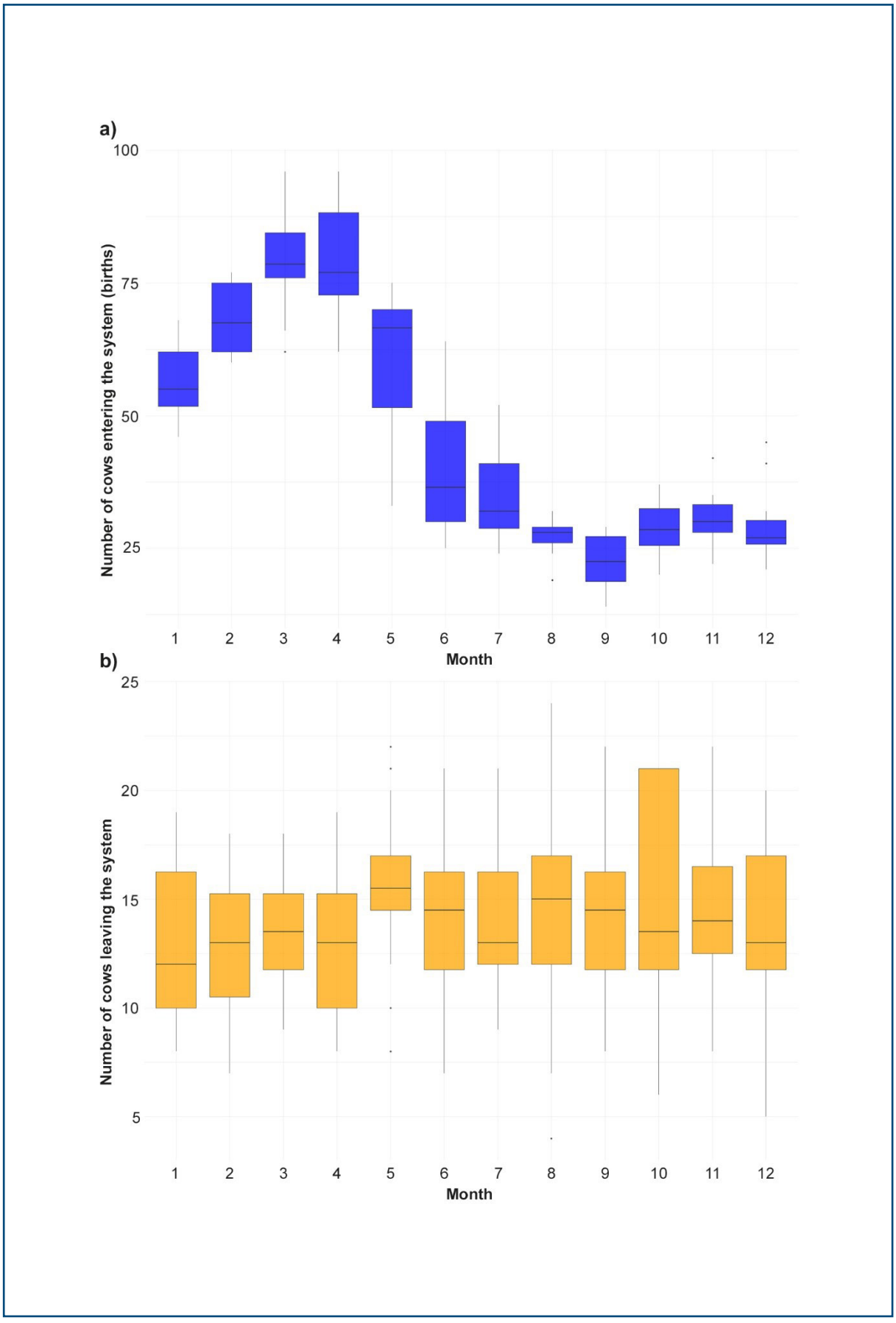
S3B Figure. The temporal trend of cattle population simulated. *The temporal trend of a population simulated for 16 years with N = 1.000 cows, Turnover = 20% and Productivity = 65%. The dotted vertical lines outline the years.*

S3C - The temporal distribution of new-borns, and leaving the system animals

S3C(a) Figure shows the number of births, while **S3C(b) Figure** shows the animals leaving the system by month. The boxplots represent the monthly values distribution (16 years).

The number of new-born stems from the set productivity (65%) while the seasonal trend reflects the birth rate **(Table 1 (a))**.

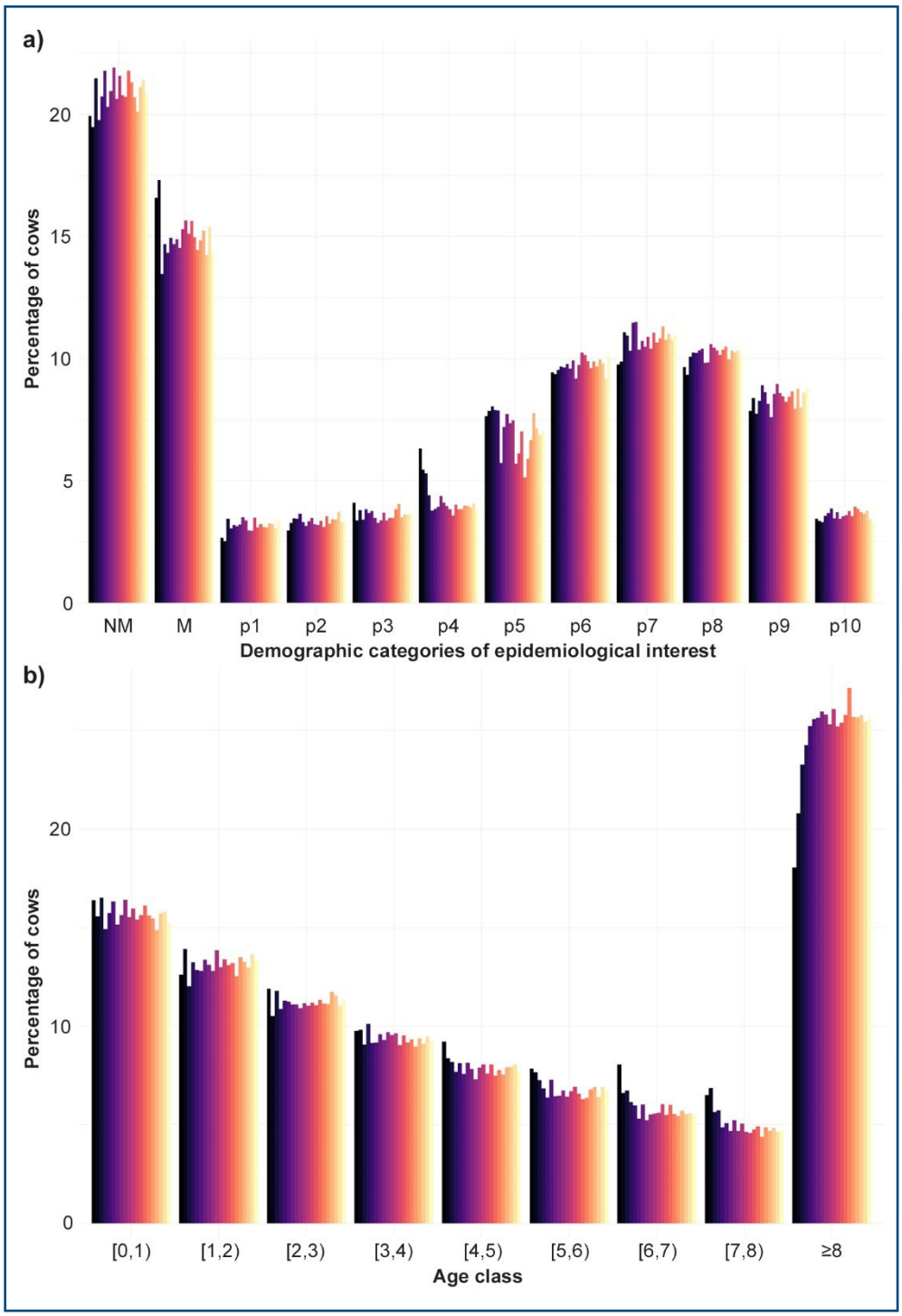
The Turnover = 20% is applied equally on all animals with respect to time, determining the (uniform) number of animals leaving the system.



S3C Figure. *The number of births (a) and the number of animals leaving the system (b) by month.*

S3D - Distribution of animals for demographic categories of epidemiological interest, and for age groups predicted

IBM model simulates the initial state of the population (t_0 = 1st January) which will then be the input data for the epidemiological model. This input is structured in a way to create the demographic categories of epidemiological interest (d) when they have reached the equilibrium. **S3D(a) Figure** shows the proportions by demographic category, while **S3D(b) Figure** by age class. The values tend to stabilize after the 10th year simulated. The input data created for the SEIR model will be those simulated for the 1st day of the 15th year.



S3D Figure. Demographic categories and age class. (a) *Percentage distribution of the demographic categories of epidemiological interest, evaluated on the 1st day of each year, for years raning from 1 to 20 (represented by coloured bars).* ***(b)*** *Percentage distribution of age groups, assessed on the 1st day of each year, for years ranging from 1 to 20. The proportions begin to stabilize after the tenth year.*