Animal Health

Original

Stochastic Simulation of an Outbreak of Avian Respiratory Disease in Camagüey

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ABSTRACT

Background. One of the reasons to study infectious diseases is to increase their control and eradication. Mathematical models could be a powerful tool to achieve that end, as they allow for optimization of limited resources, and conduct more effective measures; these models are made to predict and increase understanding of the studied phenomenon. The aim of this paper is to conduct simulations using the stochastic model known as Susceptible, Infected, Recovered (SIR), and introduce them in the curricula of students, epizootiological analyses, and decision-making.

Methods. The entrance of ten migrating birds with respiratory processes was virtually simulated on bird rearing farms averaging 5000 free-range poultry from different types. The R0 was determined, depending on the incidence.

Results. Simulation was run with a low communicability index (1.8 %), that is, 1.8 out of every 100 birds get sick after interacting with other 5 birds each, at random, for 10 days. In the absence of intervention, there would be a spike of sick animals at 20 days, surpassing 3000 birds. A basic reproductive number greater than the unit (R0=1.14) was observed, thus qualifying as an epidemic outbreak.

Conclusions. A number of simulations were made using the stochastic model with a sustainable analytical tool based on an R-free program. The need to integrate the epizootiology, epidemiology, and mathematics was demonstrated, suggesting that appropriate training should be provided by competent professionals.

Key words: epidemiology, prevention, and control, transmission, veterinary *(Source: MeSH)*

INTRODUCTION

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One of the reasons to study infectious diseases is to increase their control and eradication. Accordoingly, mathematical models could be a powerful tool to achieve that end, which allows for optimization of limited resources, and can conduct more effective measures; these models are made to predict and increase understanding of the studied phenomenon. These must be as simple as possible, being also accurate, flexible, and transparent (Vidal *et al*., 2020).

The epizooetiology of its traditional methodological scheme, like other disciplines, has relied on the mechanics of Descartes and Newton; hence, on many occasions, it keeps the traditional cause-effect system based on linear equation models, where everything functions as a machinery in a predictable way (Ivorra *et al*., 2020).

Epidemics and epizooties with complex adaptative systems. The distinctive mark of complex systems is the behavior of nonlinear and unpredictable interactions. They are structured as a large number of elements interacting among themselves, whose repeated interactions result in a collective behavior of individual parts (Caparrini *et al*., 2016; Soler, 2017) that can be captured by mathematical models.

The determination of R0 takes place when a pathogenic agent can invade or persist in a susceptible population without immunity. Pathogenic agents can evolve by increasing R0. This value is a valid indicator to measure the effectiveness of control measures required to eradicate epidemics, when R0 = 1 or R0 < 1 there is no epidemic (Vidal *et al*., 2020; Ridenhour, Kowalik, and Shay, 2015).

The current dynamics leads to the application of transdisciplinary theories. Therefore, universities are challenged with leading changes in educational processes that allow future public health care professionals to use transdisciplinarity as a tool to strengthen research and knowledge-based dialog (Castilla, Guerra, and Villadiego, 2018).

Changes in the utilization of artificial intelligence, new ways of distance learning, distance medical calls, and so on, are taking place, proving that to achieve resilience, it is important to incorporate strong adaptative methods that demand integrative approaches (Martins, 2020).

Few human diseases are found to have a link to animals (influenza, tripanosomiasis, and an extensive list of zoonoses), a complex dynamic that can be observed in critical mathematical models for sanitary control policy implementation (Lloyd-Smith *et al*., 2009).

In general, simulation(Ortiz, Vázquez, and Aguilar, 2020) permits to study a system without experimenting on the real, and conduct sampling experiments on a system model. A model is a set of variables together with mathematical equations that relate them. Real experiments are highly costly, slow, and their tests are sometimes destructive, and violate medical ethics. The aim of this paper is to conduct simulations using the stochastic model known as *Susceptible, Infected,* *Recovered* (SIR), and introduce them in the curricula of students, epizootiological analyses, and decision-making.

MATERIALS AND METHODS

The basic SIR model (Susceptible-Infected-Recovered) by Kermack and McKendrick is based on behaviors, where the population studied is divided into epidemiological classes, and a flow among them is described (Vidal, 2020; Manlove *et al*., 2019).

In this type of mathematical models, the basic reproductive model (R0) shows the mean of the number of secondary cases that a primary patient will cause in a population with no previous immunity. The following model is used to determine the reproductive number (R0):

$$R0 = \beta \, So \, (1/\gamma)$$

Where:

β = communicability index

So = susceptible without immunity at start

γ= duration of the disease

β So is the number of new emerging cases (incidence)

$1/\gamma$ is the infection duration average

A stochastic model was simulated (Rincón, 2012) using EpiModel, from R (R_Core_Team, 2021) , with the entry of ten sick migrating birds with respiratory processes on bird raising farms with a total average of 5000 free-range birds of different types. R0 was determined (RO package, R program), depending on the incidence.

RESULTS

Simulation was run with a low communicability index (1.8 %), that is, 1.8 out of every 100 birds get sick, having every bird interacting with other 5 birds, at random, for 10 days. In the absence of intervention, there would be a spike of sick animals at 20 days, surpassing 3000 birds.

A basic reproductive number greater than the unit (R0=1.14) was observed, thus qualifying as an epidemic outbreak (Ke, Romero-Severson, Sanche and Hengartner, 2021).

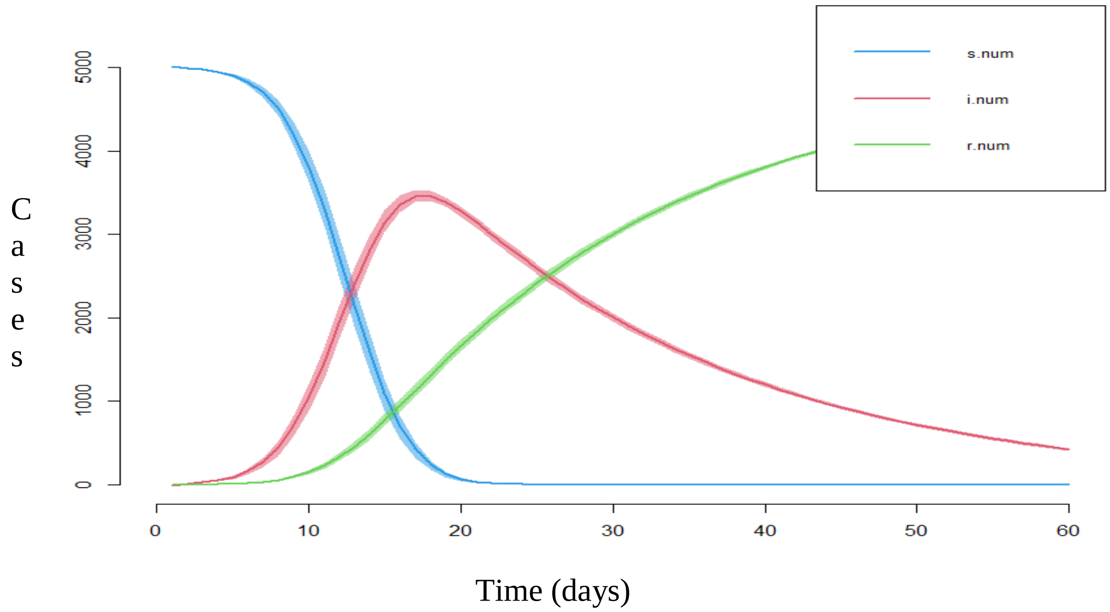

Figure 1. Five migrating birds make contact with 5000 free-range birds at random. The red line represents the infected population (i), the blue line represents the susceptible healthy population (s), and the green line represents the recovered or deceased animals (r).

DISCUSSION

A health care professional (humans and animals) is capable of assessing the outcome sustainably; in fact, they must diagnose and solve the problem in the first 10 days, since the exponential growth of the incidence could go over 3000 cases before 20 days. Each primary sick animal is capable of infecting 1.14 birds. Waiting until achieving herd immunity is not convenient (Trincado, 2020).

Disease dispersion patterns in people have been studied, and linked to the domestic and wild animal worlds (Torres *et al*., 2020). In the particular case of migrating birds, with a great moving capacity, they can acquire and spread infections by pathogenic agents which are harmful to humans (such as the highly pathogenic virus of bird influenza, the West Nile virus, *Chlamydia psittaci*, and others, especially found in migrating birds (Contreras *et al*., 2016; Sánchez *et al*., 2020).

Wild aquatic birds are the main natural reservoir on the influenza viruses, and have participated in the arrangement of pandemic viruses, as responsible for outbreaks of avian flu in domestic and wild species (Sánchez *et al*., 2020).

People tend to create affective bonds with animals, including birds, with no perception of the risk they are exposed to. Frequently, birds live in patios and yards, without required distancing, and are often caressed by their owners. This social behavior, among other factors, influences on the likelihood of contagion to humans (Gibb *et al*., 2020)

The development of cooperative competencies, as well as self-recognition of deficiencies in understanding some concepts, were observed in students during mathematical trainings done on Moodle. (Perera *et al*., 2020).

Distance education, in its part, has quickly spread out in university systems internationally, due to the advantages it has, particularly the utilization of Information Technologies (IT), through virtual environments that favors access to courses from everywhere; the only requirement is to be online (Céspedes *et al*., 2016). A methodological change is required to enable a transit from a content-teacher-centered method to a one focused on e-activities, and students (Quiroz-Silva, 2017).

A field veterinarian needs a transdisciplinary educational style that includes these mathematical models systematically to solve several different problems faced in real life. Accordingly, changes in the organization are necessary, in order to modify working styles, and self-organizational forms of the activity (Cárdenas, and Estrada, 2021; Belcher *et al*., 2016).

CONCLUSIONS

A number of simulations were made using the stochastic model with a sustainable analytical tool based on an R-free program.

The need to integrate the epizootiology, epidemiology, and mathematics was corroborated, so appropriate training should be provided by competent professionals to students in these aspects, particularly animal and public human health care.

It is convenient to systematize mathematical model trainings both in face to face and distance education.

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AUTHOR CONTRIBUTION

Conception and design of research: JABB; data analysis and interpretation: JABB; redaction of the manuscript: JABB, RHZ, MAE.

CONFLICT OF INTERESTS

The authors declare no conflict of interests.