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A Study on Mathematical Model of *Caprine Arthritis Encephalitis* (CAE) and Development of Animal Quarantine Information System Adapted for Small Island

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** Regular Paper*

***Abstract*:** This paper proposes a mathematical model of *Caprine arthritis encephalitis* (CAE), which is a disease causing significant economic damage to the goat farming industry, and reports the application of this model to the development of an information management system of animal quarantine to overcome this disease. The mathematical model of CAE was derived from the AIDs model in human case because epidemical characteristics of these diseases including infection pass are similar. This model can be expressed by simultaneous differential equations. Simulations using a new model were performed according Euler's and Runge-Kutta method using numerical analysis software. In each method, strong convergence was observed and the results were similar. The design of an information management system of animal quarantine was proposed as an application of the new model. System design was constructed on the assumption that in subtropical islands, the expected development of information infrastructure and utilization will become valuable in the future.

***Keywords*:** Animal quarantine, Animal infectious disease, Information management system, Small islands

1. Introduction

Caprin arthritis encephalitis (CAE) is a viral disease caused by the CAE virus (CAEV), which is a lentivirus of the family Retroviridae. The disease occurs all over the world including Southeast Asia. The CAEV transmission is due mainly to breast milk. Approximately 10% of CAEV-infected animals may develop clinical symptoms, such as chronic persistent arthritis, respiratory distress, and encephalitis. A CAEV infection can reduce the milk yield and affect the quality of milk production in goats [1]. In some countries, CAE has been designated a infectious diseases to be managed legally.

Various kinds of mathematical model of infectious diseases exist. The simplest model is known as the SIR model (SIR is a initials of Susceptible, Infected and Recovered.). The SIR model was proposed by W. O. Kermack and A. G. McKendrick in 1927 [2]. Under this SIR model, the goat population is divided into three categories: susceptible animal (S), infected animal (I) and removed animal(R). The increase and decrease in the each category are indicated by differential equations.

The infection route of CAEV is mainly vertical

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transmission through breast milk and horizontal transmission by sexual intercourse. This feature is similar to the case of HIV in humans. Therefore, a CAEV model can be proposed by referring to the mathematical model of HIV. The vertical transmission of HIV can also occur through the placenta. On the other hand, when constructing a mathematical model, it is not necessary to discriminate between a breast milk infection or placental infection.

Kawase [3] proposed a mathematical model for HIV infections in humans. In this model, the population is divided into 6 categories, young, elderly, men and women that are infected or non-infected. In addition, Kawase defined the following 5 parameters: force of infection, which includes vertical transmission and sexual infection (male to female, male to male, female to male and female to female).

Based on the number of mathematical research results on infectious diseases including Kawase's model, a mathematical model of CAE was examined in the view of system control engineering.

Economic activities, movement of people, and freight traffic are expected to augment due to TPP (Trans-Pacific Strategic Economic Partnership Agreement) promotions, leading to an increase in the livestock and animal feed quantity of the same area. Consequently, the quarantine system to prevent infectious diseases on livestock animals is needed to reinforce more than before. The outbreak of infectious diseases, such as foot-and-mouth disease in the Miyazaki prefecture, Japan and Korea, would be catastrophic for the local livestock industry [1, 2]. Southeast Asia contains some countries with numerous small islands, if some infectious disease spreads to the island, then the local livestock industry can be destroyed almost entirely. Even if this subject was placed under direct central government control, some technical difficulties would be challenged. The underdevelopment of the infrastructure of information communications and transportation, due to the remote island location, are hindrances to the realization of infectious disease prevention.

The second objective is to discuss the outline design of the system to be prepared for the realization of an information management system of livestock quarantine to prevent infectious diseases. This paper proposes a framework of this new information management system to realize animal quarantine in small islands.

2. Mathematical model of CAE

To recognize the infected animals of CAE in small islands and measure the effectiveness of information management system of livestock quarantine, it is important to develop a new structure model of mathematical formula of CAE infections. Therefore, this study developed a new model based on the conventional model of infectious diseases. Generally, the SIR model is a mathematical model for infectious diseases. Under this model, the goat population is divided into three categories, susceptible animals (S), infected animals (I), removed animals (R). The increase and decrease in each category are then indicated by the differential equations as follows:

$$\frac{dS}{dt} = -\beta SI \tag{1}$$

$$\frac{dI}{dt} = \beta SI - \gamma I \tag{2}$$

$$\frac{dR}{dt} = \gamma I \tag{3}$$

where β is the infectivity, and γ is the recovery rate or isolation rate. This model, however, does not reflect the phenomena of a natural increase or decrease in the number of animals (such as birth, natural death, and in case of livestock; forwarding and being slaughtered). With the addition of the coefficient of the number of births λ, death rate μ, the model can changed to the following equations.

$$\frac{dS}{dt} = (\lambda - \mu)S - \beta SI + hR \tag{4}$$

$$\frac{dI}{dt} = -(\mu + \delta)I + \beta SI - fI \tag{5}$$

$$\frac{dR}{dt} = -\mu R + fI - hR \tag{6}$$

The infectivity of CAE is assumed to be proportional to the number of the infected animals by the above formula. Because the CAE infection route is recognized by mother's milk (vertical infection), reproduction or spray of virus (horizontal infection), another way to measure the infectivity of CAE is needed to reflect the infection route. The aim of this study was to improve the above formula model based on the report of Kawase's HIV infection model [4]. The infectivity was assumed to be proportional not only to the number of the infected animals but to the infection rate. Under this model, the gender ratio is one to one; η is the birth rate coefficient, d is the prevention rate, and e is the vertical infection rate. The adult and child animal model were differentiated and described as follows:

$$\frac{dJ_s}{dt} = \eta F_s + (1-e)\eta F_I - \mu_J J_S - gJ_S \tag{7}$$

$$\frac{dJ_I}{dt} = e\eta F_I - (\mu_J + \delta)J_I - gJ_I \tag{8}$$

$$\frac{dM_S}{dt} = \frac{1}{2}gJ_S - \mu M_S - \beta_1(1-d)\frac{F_I}{F_S+F_I}M_S - \beta_2(1-d)\frac{M_I}{M_S+M_I}M_S \tag{9}$$

$$\frac{dM_I}{dt} = \frac{1}{2}gJ_I - (\mu+\delta)M_I + \beta_1(1-d)\frac{F_I}{F_S+F_I}M_S + \beta_2(1-d)\frac{M_I}{M_S+M_I}M_S \tag{10}$$

$$\frac{dF_S}{dx} = \frac{1}{2}gJ_S - \mu F_S - \beta_3(1-d)\frac{M_I}{M_S+M_I}F_S - \beta_4(1-d)\frac{F_I}{F_S+F_I}F_S \tag{11}$$

$$\frac{dF_I}{dx} = \frac{1}{2}gJ_I - (\mu+\delta)F_I + \beta_3(1-d)\frac{M_I}{M_S+M_I}F_S + \beta_4(1-d)\frac{F_I}{F_S+F_I}F_S \tag{12}$$

where J_s is a not-infected child animal, J_I is an infected child animal, M_S is an uninfected adult male animal, M_I is an infected adult male animal, F_S is an uninfected adult female animal, and F_I is an infected adult female animal

The coefficient of the kid mortality was indicated by η_J, and the growth rate per time unit was indicated by *g*. The infectivity indicated by β provides the matches as follows:

Uninfected adult male・Infected adult female
Uninfected adult male・Infected adult male
Uninfected adult female・Infected adult male
Uninfected adult female・Infected adult female

Because mating by the same sex does not need to be considered in the case of goats, the last term should be omitted in Eqs. (9) to (11). Hence, the following equations were derived:

$$\frac{dF_I}{dx} = \frac{1}{2}gJ_I - (\mu+\delta)F_I + \beta_3(1-d)\frac{M_I}{M_S+M_I}F_S + \beta_4(1-d)\frac{F_I}{F_S+F_I}F_S \quad (12)$$

$$\frac{dJ_I}{dt} = e\eta F_I - (\mu_J+\delta)J_I - gJ_I \quad (13)$$

$$\frac{dM_S}{dt} = \frac{1}{2}gJ_S - \mu M_S - \beta_1(1-d)\frac{F_I}{F_S+F_I}M_S \quad (14)$$

$$\frac{dM_I}{dt} = \frac{1}{2}gJ_I - (\mu+\delta)M_I + \beta_1(1-d)\frac{F_I}{F_S+F_I}M_S \quad (15)$$

$$\frac{dF_S}{dx} = \frac{1}{2}gJ_S - \mu F_S - \beta_3(1-d)\frac{M_I}{M_S+M_I}F_S \quad (16)$$

$$\frac{dF_I}{dx} = \frac{1}{2}gJ_I - (\mu+\delta)F_I + \beta_3(1-d)\frac{M_I}{M_S+M_I}F_S \quad (17)$$

The above equations were used in the simulation. Fig. 1 shows the results of the simulation and Table 1 lists the initial values and parameters. Different values were used for each infection speed of males and females. The vertical infection rate was 0.8 and the horizontal infection rate was 0.3.

The simulation effectively visualized the features of the infection spread of CAE by vertical and horizontal infection. Improving the prevention rate of the horizontal infection is very important for preventing the spread of infection for a long-range period. On the other hand, there are two points to be improved to implement higher-level accuracy simulations. One of them is that the demographic model of human beings was adopted. In the case of human beings, there was no seasonal deviation for the frequency of sexual intercourse and child birth. Human beings' deaths are considered as the same. On the other hand, goats have seasonal fertility in that mating occurs is in the fall and reproduction occurs in spring. That is, any particular calculation for goat animal demographics is not taken into consideration under this simulation.

Another point is that new parameters are needed to recognize the change in the numbers of the goats alive and slaughtered antibody-positive animals. This is because the faster implementation of quarantine is needed for infection prevention on the site of animal feeding. The finding and slaughtering of antibody-positive animals of goats are

Table 1. Experimental Parameters of the simulations.

Parameters	Values	Descriptions of Parameters
η	3×10^{-3}	birthrate per time unit
e	0.8	vertical infection rate
μ_J	0.05	mortality of kid goats
δ	0.1	direct mortality of infectious disease
g	1×10^{-6}	growth rate of per time unit
d	0.3	prevention rate of the horizontal infection
β_1	0.3	infection speed (female to male goat)
β_2	0.4	infection speed (male to female goat)
μ	3×10^{-3}	mortality rate

different measures from the case of human beings. By introducing these new parameters, the simulations are considered to be closer to the real situation.

Both cases show the behavior of the similar solution. Generally, the accumulation of errors by Euler's method is too large, and the solution can diverge easily. On the other hand, in this study, Euler's method obtained precise numerical solutions and the solution was similar to the solution using the extended Runge-Kutta method. These results were caused by following reasons. Generally, the change in the population was viewed on a daily basis when the trend of the infection was considered. Therefore, the proposed model is reasonable. In addition, the new model considered the long span of livestock life cycle from birth to slaughter. In other words, even if it takes a small step, the changes are too small, so it is too difficult to understand the phenomenon in time increments of a few minutes or a few seconds. Furthermore, performing a numerical integration on a fine time interval in the assessment of morbidity and mortality is meaningless. The changes in the trajectory of the epidemic model represented by CAE model and SIR model were slow enough, this can be understood as a function capable of sufficient linear approximation piecewise. On the other hand, for the model proposed here, a study of the consistency of the precise numerical solution of differential equations and difference equations is a stage that is currently underway.

The basis of the SIR model proposed by Kermack and

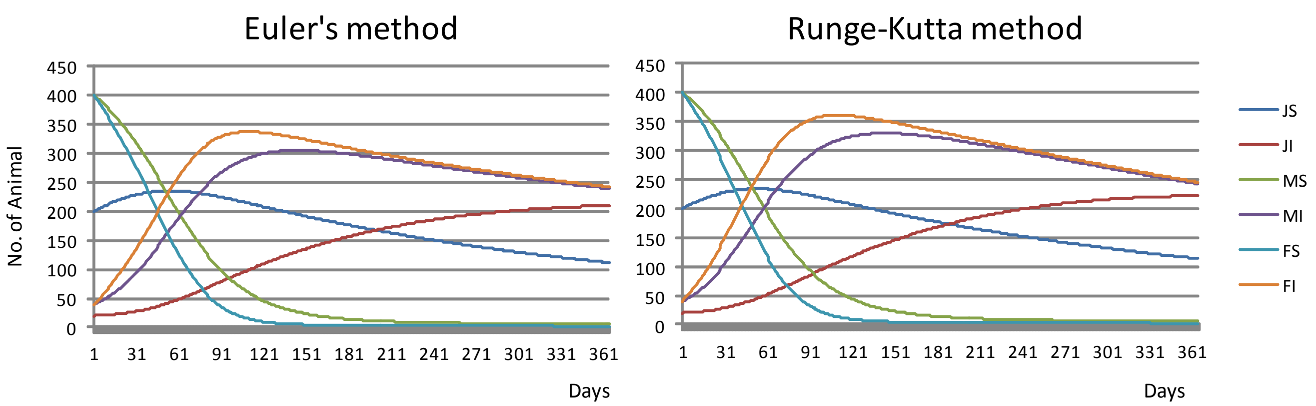

Fig. 1. Results of the simulation by Euler's and Runge-Kutta method using numerical analysis software.

McKendrick [2], which is the mathematical model for representing the dynamics of various infectious diseases, has long been proposed. One of them is a study of the transmission of sexually transmitted diseases. Research has progressed significantly to the global epidemic of HIV using mathematical models in sexually transmitted diseases. Several mathematical modeling studies based on the concept of the ‘‘HIV transmission rates’’ have recently appeared in the literature. The transmission rate for a particular group of HIV-infected persons is defined as the mean number of secondary infections per member of the group per unit time [5, 6]. An estimated 1,178,350 persons are living with HIV in the US at the end of 2008 [7] and approximately 56,300 people acquire HIV each year [8].

Research on the mathematical models of zoonotic disease is progressing, e.g. the mathematical model many have proposed regarding the propagation of Rift Valley fever, which is transmitted by mosquitoes. Métras et al. [9] proposed a mathematical model of Rift Valley fever. Gaff et al. [10] proposed a compartmental model to explore the mechanisms of RVFV circulation including Aedes and Culex mosquitoes and livestock population, in which each adult mosquito population is divided into classes containing susceptible, exposed and infectious individuals and the livestock population is classified as susceptible, exposed, infectious, and recovered. Gao et al [11] simulated the prevalence of the disease in Egypt based on the studies.

A large difference between our model and other models is including of real reproductive of animals, or not. A study of the mathematical models of infectious diseases in the past have been done mainly in humans. Research has been conducted on livestock, but livestock are anniversary reproductive in many cases. This indicates that in the transmission of infectious diseases related to reproduction, it is possible to carry out accurate predictions and cache simulations.

3. Development of the Animal Quarantine Information System Adapted for Small Islands

Foot-and-mouth disease occurred in the Miyazaki Prefecture of Japan in 2010. FMD is an extremely contagious viral infection that causes significant economic losses, in this case more than 200 billion yen. In addition, it had a huge impact on the surrounding industries, such as tourism. As a lesson on the occurrence of FMD, the Government of Japan implemented quarantine exercises in each prefecture. In the case of FMD, it is important that diagnosis of the oral, hoof, nipple, and nasal cavity be made. The report of the government suggests taking advantage of mobile terminals to quickly share such information. In addition, high resolution pictures taken by a camera mounted in mobile phone terminals would be useful. Therefore, it would be necessary to improve the operation of mobile phone systems including device management.

A number of efforts have been made to take advantage of information and communication technology to prevent the threat of livestock infections. Studies utilizing technologies, such as RFID, to try to apply to the management of animal welfare and quality control and identification of livestock have become popular. McKean [13] and Saa [14] suggested the importance of electronic technologies in the identification and the traceability of animals in agriculture.

Efforts for the disclosure of the correct information on the animal production in association with the NLIS to consumers was made in Australia. This project is called the FARMA project [11]. The FARMA project is intended to manage the information (i.e. feeding, veterinary medicine, etc.) collectively. The FARMA project is an advanced, leading ICT project in the agricultural sector.

This project can be used to predict the epidemics of infection. Mathematical models of infectious diseases can be also effective in the planning of infectious diseases control. This chapter describes the design of a quarantine system of goats by the application of a mathematical model for CAE proposed in the previous section. In designing the protection system, it was decided to consider the system requirements assuming concrete regional.

Tarama Island of the Ryukyu Islands was selected for the island model, which is 30km away from the nearest island, and the people and freight are transported by sea or air. The communication infrastructure is underdeveloped due to the remote island location; microwave communication is used for internet connections. Health officials for infection prevention are two people in the island; one is from the Tarama Village office and is in charge of the livestock section, and the other is a veterinarian deployed on the island. No goat expert veterinarians are deployed at ordinary times; a goat expert would be sent only in emergencies. Therefore, the suspected affected animal will be reported to the nearest health officials by the goat feeder’s contact.

Goats were selected as the livestock model because its

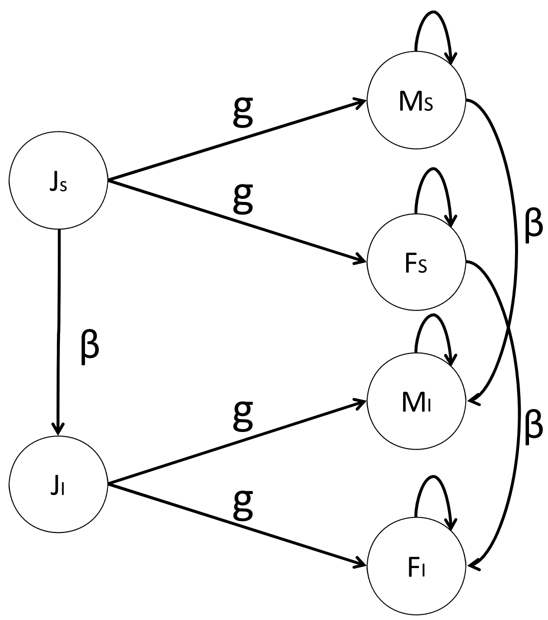

Fig. 2. State transition diagram of the CAE model.

milk, meat and hair are products for commercial use. Therefore both of milk and meat goat are the appropriate choices as a livestock model.

To realize the placing control of infectious diseases on livestock animals under the local people and system concerned, a variety of information should be collected for central control, such as the information of livestock animals, feeder, feeding place, management of livestock reproduction records, and various information of slaughterhouse. The related databases by organic coordination would be necessary for mutual integration. Owing to remote island situation, offices or organizations for the inspection for animal infection prevention and quarantine can be distant from the place of the livestock animals. Therefore, information sharing among the people concerned in a short time is crucial. This chapter provides an example design of information management system for livestock quarantine suited to small islands with a discussion of the trial method to overcome such difficulties due to remoteness. Fig. 3 presents an image of the system.

Fig. 4 shows the structure of the proposed system. The system contains three sub systems; "remote-island-line sub

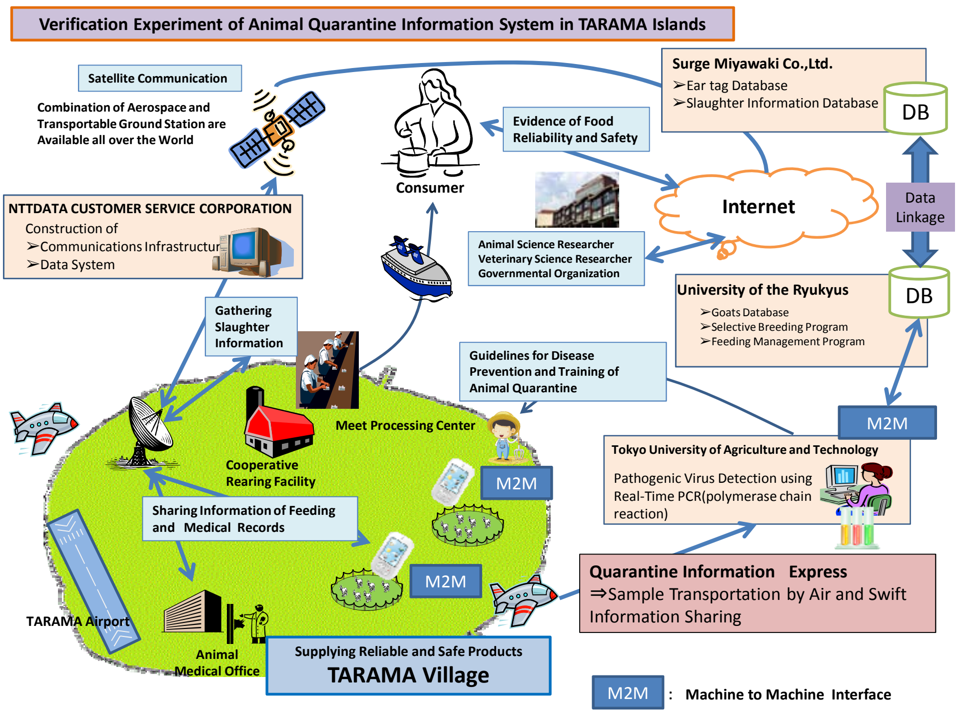

Fig. 3. System Design and Operation Plan of Animal Quarantine System in Tarama Island.

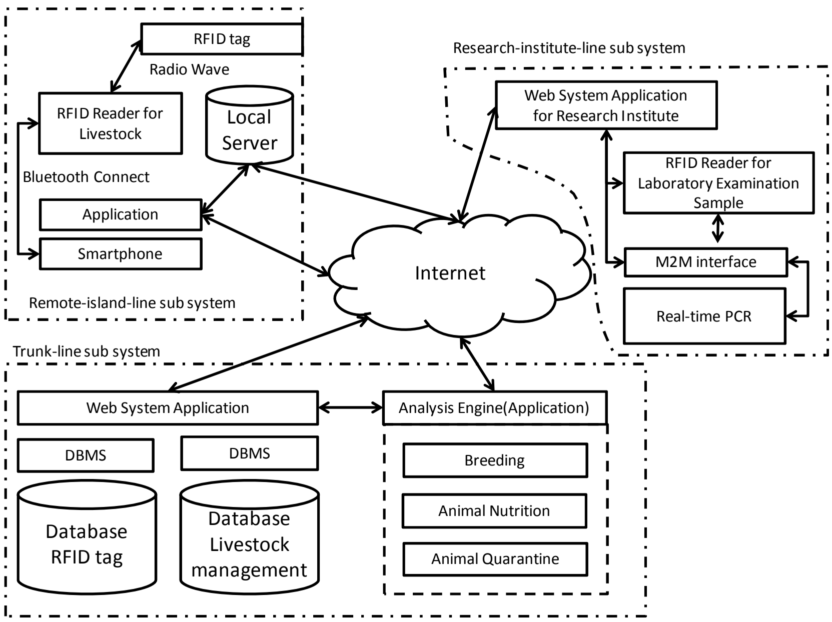

Fig. 4. Diagram of the System Configuration of an Animal Quarantine System.

system" to collect and share various data of the remote island, "research-institute-line sub system" to collect analyzed information from livestock infectious disease research, and "trunk-line sub system" to integrate and analyze all the information collected.

The remote-island-line sub system contains a data collecting structure with a mobile phone terminal to collect data from individual animal feeders, and with the screening-results collection system of the animals' infectious disease at the slaughterhouse. The built-in client server of the system works to keep information on those for a certain amount of time. Under this sub system, an information backup server was established in the case of a possible impairment of information communication. The research-institute-line sub system works as an information collecting arrangement from the data analysis device for medical examinations, such as real-time PCR. The system contains a M2M interface of the connecting the database with the data analysis device and management coordination of the individual livestock number.

The trunk-line sub system was constructed from three parts; database (operated by private enterprise) to coordinate the number of the ear tags placed into the animal's ear, and a server to control the other data, and software to analyze the data. Among the software, Hirata et. al. [4] reported details of the invention related to improved varieties and livestock nutrition.

A mathematical model of CAE proposed in the previous section was mounted on the quarantine software to predict epidemic infections and promote the implementation of appropriate protection measures.

5. Conclusion

Historically, humans have constantly been under the threat of epidemics. In addition, foot-and-mouth disease and mad cow disease has caused extensive damage to the livestock industry. If a livestock epidemic spreads over the world, the safety of meat will be threatened, resulting in a potential food crisis. The bird flu spread in the birds and animals world is the same as that in human world. Consequently, avian influenza is raging in human society around the world. Therefore, the construction of mathematical models for infectious zoometric diseases is very important for understanding the diffusion of infectious diseases.

This paper proposed a new mathematical model of CAE that affects the great deal of economic damage to goat farming. The development of an information management system of animal quarantine to overcome the disease using the proposed model was discussed. The simulations using the new model were performed using Euler's and Runge-Kutta method by numerical analysis software. In each method, strong convergence was observed and similar results were obtained. For disease eradication, the total information management system of animal quarantine can be developed using the new model. An analysis of the stability condition of the system is currently underway.

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References

[1] D. S. Adams et al, "Transmission and control of caprine arthritis–encephalitis virus," American. Journal of Veterinary Research. No.44, pp.1670–1675, 1983. Article (CrossRef Link)

[2] W. O. Kermack et al, "A Contribution to the Mathematical Theory of Epidemics," *Proc. Roy. Soc. of London. Series A*, Vol. 115, No. 772, pp. 700-721 August 1927 Article (CrossRef Link)

[3] Y. Kawase, "Mathematical model of HIV infection transmission," Graduation thesis in Ritsumeikan university, 2009 Article (CrossRef Link)

[4] T. Hirata et al., "Development of Quality Control and Breeding Management System of Goats Based on Information and Communication Technology," *Studies in Informatics and Control,* Vol. 22, No. 1, March 2013. Article (CrossRef Link)

[5] Holtgrave DR. Estimation of annual HIV transmission rates in the United States, 1978–2000. J Acquir Immune Defic Synd. 2004;35:89–92. Article (CrossRef Link)

[6] Holtgrave DR, Pinkerton SD. Can increasing awareness of HIV seropositivity reduce infections by 50% in the United States? J Acquir Immune Defic Synd. 2007;44:360–3. Article (CrossRef Link)

[7] Centers for Disease Control and Prevention. HIV surveillance—United States, 1981–2008. Morbid Mortal Wkly Rep. 2011;60:689–93. Article (CrossRef Link)

[8] Hall HI, Song R, Rhodes P, et al. Estimation of HIV incidence inthe United States. JAMA. 2008;300:520–9. Article (CrossRef Link)

[9] Métras, R., Collins, L. M.,White, R. G., Alonso, S., Chevalier, V., Thuranira-McKeever, C., & Pfeiffer, D.U. (2011). Rift Valley fever epidemiology, surveillance, and control: what have models contributed? Vector-Borne Zoonotic Dis., 11, 761–771. Article (CrossRef Link)

[10] Gaff, H. D., Hartley, D. M., & Leahy, N. P. (2007). An epidemiological model of Rift Valley Fever. Electron. J. Differ. Equ., 115, 1–12. Article (CrossRef Link)

[11] Daozhou Gao • Chris Cosner •Robert Stephen Cantrell • John C. Beier •Shigui RuanBull, Modeling the Spatial Spread of Rift Valley Fever n Egypt Math Biol (2013) 75:523–542 Article (CrossRef Link)

[12] Athanasios S. Voulodimosa,, Charalampos Z. Patrikakisa, Alexander B. Sideridis, Vasileios A. Ntafis, Eftychia M. Xylouri, A complete farm management system based on animal identification using RFID technology, Computers and Electronics

in Agriculture(2010), 70(2), 380–388 Article (CrossRef Link)

[13] McKean, J., 2001. The importance of traceability for public health and consumer protection. Revue Scientifique et Technique 20 (2), 363–371. Article (CrossRef Link)

[14] Saa, C., Milan, M., Caja, G., Ghirardi, J., 2005. Cost evaluation of the use of conventional and electronic identification and registration systems for the national sheep and goat populations in Spain. Journal of Animal Sciences 83,1215–1225. Article (CrossRef Link)

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