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ORIGINAL ARTICLE

Prediction Forecast for *Culex tritaeniorhynchus* Populations in Korea

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Abstract

Objectives: Japanese encephalitis is considered as a secondary legal infectious disease in Korea and is transmitted by mosquitoes in the summer season. The purpose of this study was to predict the ratio of *Culex tritaeniorhynchus* to all the species of mosquitoes present in the study regions.

Methods: From 1999 to 2012, black light traps were installed in 10 regions in Korea (Busan, Gyeonggi, Gangwon, Chungbuk, Chungnam, Jeonbuk, Jeonnam, Gyeongbuk, Gyeongnam, and Jeju) to capture mosquitoes for identification and classification under a dissecting microscope. The number of mosquitoes captured/week was used to calculate its daily occurrence (mosquitoes/trap/night). To predict the characteristics of the mosquito population, an autoregressive model of order p (AR(p)) was used to execute the out-of-sample prediction and the in-sample estimation after presumption.

Results: Compared with the out-of-sample method, the sample-weighted regression method's case was relatively superior for prediction, and this method predicted a decrease in the frequency of *Cx. tritaeniorhynchus* for 2013. However, the actual frequency of this species showed an increase in frequency. By contrast, the frequency rate of all the mosquitoes including *Cx. tritaeniorhynchus* gradually decreased.

Conclusion: The number of patients with Japanese encephalitis has been strongly associated with the occurrence and density of vector mosquitoes, and the importance of this infectious disease has been highlighted since 2010. The 2013 prediction indicated an increase after an initial decrease, although the ratio of the two mosquito species decreased. The increase in vector density may be due to changes in temperature and the environment. Thus, continuous prevalence prediction is warranted.

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1. Introduction

Japanese encephalitis is considered as a secondary legal infectious disease in Korea and is one of the main mosquito-borne infectious diseases of the summer season. *Culex tritaeniorhynchus*, which transmits Japanese encephalitis, is dispersed not only in Korea, but also in other areas such as Japan, China, Southeast Asia, India, and Pakistan. This major mosquito species infects approximately 68,000 individuals each year, resulting in approximately 20,000 deaths annually [1−3].

Since the first reported incidence of the disease in Korea from the U.S. forces stationed in the Incheon area in 1946 [4,5], the incidence of Japanese encephalitis has significantly increased since 1949, affecting at least 5616 people, and resulting in 2797 deaths [6,7]. Moreover, 1000−3000 individuals were infected with the disease each year until the 1960s. The incidence of Japanese encephalitis significantly decreased in the 1970s compared with the 1960s. From 1984 to 2009, this infectious disease was almost eradicated, with less than 10 cases reported every year. However, 28 cases were reported in 2010, with a possibility of an increase in vector mosquito density due to changes in temperature and the environment. Thus, continuous prevalence prediction is warranted.

Seasonal identification is very important in managing mosquitoes [8]. It has been reported that the rapid decrease in the incidence of Japanese encephalitis between 1960 and 1970 was due to the decrease in the density of the vector mosquito [9−11], which is similar to that observed in Japan [12,13].

In this research, black light traps were installed in 10 regions of Korea (Busan, Gyeonggi, Gangwon, Chungbuk, Chungnam, Jeonbuk, Jeonnam, Gyeongbuk, Gyeongnam, and Jeju) for the last 12 years from 1999 to 2012 and mosquito data were collected. Using the data collected, a simple AR(p) model was used to estimate and predict the ratio of Japanese encephalitis vector mosquitoes. Thus, this research was conducted to predict mosquito occurrence in order to control the incidence of Japanese encephalitis.

2. Materials and methods

2.1. Data

Data for this investigation were directly acquired by the National Institutes of Health from the Public Health and Environment Research Institute of 10 regions in Korea (Busan, Gyeonggi, Gangwon, Chungbuk, Chungnam, Jeonbuk, Jeonnam, Gyeongbuk, Gyeongnam, and Jeju), two times a week from May to October (data collection period: 1999−2012). In addition, this investigation used the mosquito occurrence density data of Japanese encephalitis prediction programs of the last 14 years using the mosquito classification key of the regional health centers.

2.2. Collection region and equipment

Cowsheds have been identified as the main region of vector mosquito occurrence in all the 10 Korean regions. A black light trap, which is commonly used for mosquito density studies, was installed at a height of 1.5−1.8 m within the cowshed. The light traps were operated two times a week from 19:00 PM to 06:00 AM the following day [14]. The mosquitoes collected in the trap were carefully transported to the laboratory. Then, the mosquitoes were placed in a plastic bag with a cotton ball of ether or chloroform. Next, the plastic bag was completely sealed or kept in the freezer for at least 2 hours. After killing, the mosquitoes were identified and classified by observing them under a dissection microscope. Based on the number of mosquitoes collected, the daily average density of mosquitoes was calculated (i.e., mosquitoes/trap/night).

2.3. Preliminary data analysis

Figure 1 shows the distribution of *Cx. tritaeniorhynchus* and all other mosquitoes in Korea by week from 1999 to 2012. The population of all mosquitoes including *Cx. tritaeniorhynchus* changed at 2−3-year intervals. Moreover, after 2010, the *Cx. tritaeniorhynchus* population decreased compared with the population of all other species of mosquitoes. These changes might have been caused by an increase in its natural enemies or temperature, although this analysis did not include the analysis of factors affecting mosquito density and mainly focused on predicting the population dynamics of mosquitoes.

2.3.1. Unit root test

The time series using the unit root test is relatively unstable. Therefore, this may cause problems of spurious regression, especially when using general regression analysis. Thus, the variables and mosquito data used in this study were executed using a unit root test to verify whether these could be considered as stable time-series data. The augmented Dickey−Fuller test [15] and Phillips−Perron test [16] were used for the unit root test.

Table 1 shows the results of the unit root test using the mosquitoes collected/week. In the table, "none" indicates the absence of a constant term and trend; "intercept" indicates a constant term; and both constant term and trend are considered as "trend." The null hypothesis that the unit root exists in the rates of all mosquitoes and *Cx. tritaeniorhynchus* was rejected and the unstable-level variables were used in the analysis.

2.3.2. Summary statistics

Table 2 shows the results of the statistical analysis. The ratio of all mosquitoes to *Cx. tritaeniorhynchus* was positive (+). The density of all mosquitoes was highest in 2003 (87,194 mosquitoes). The density of