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1. Introduction

Foot-and-Mouth Disease (FMD) is a highly contagious viral disease of cloven-hoofed animals and is commonly associated with the movement of animals or the shipment of food contaminated with the FMD virus (Kitching and Alexandersen, 2002; Mahy, 2005). Risk of infection of the virus exists at different levels in animal products even after meat processing (Blackwell et al., 1982; Chou and Yang, 2004). Moreover, rapid worldwide distribution of animals and their products through rapid international transportation have diminished the effect of natural geographic barriers on exotic animal disease (Blackwell, 1984). In 1997, Taiwan suffered a serious FMD outbreak that resulted in the destruction of more than 4 million pigs (Howard and Donnelly, 2000). This disaster was strongly suspected to be the result of transboundary smuggling of animal products. Although Taiwan had regained recognition by the World Organization for Animal Health (OIE) in 2003 for being FMD-free with vaccination, more attention must be placed on the risk of FMD transmission from carrier animals and related products which are transported intentionally or unintentionally by people (Pharo, 2002; Adkin et al., 2004; Amass et al., 2005).

The introduction of FMD virus into a foreign country via meat products can be assessed by the risk assessment study based on a sequence of factors: the prevalence of FMD in the origin country, the commodity factor, and the transportation factor (DEFRA, 2003). In addition, our previous studies of illegally carried animal-products by air passengers at international airports in Taiwan showed that the observed violation risks were underestimated, and a two fold violation increase was predicted after the detective beagle was put into service (Shih et al., 2005). The international passengers who illegally carry animal products into Taiwan played an important role in risk evaluation (Shih et al., 2006). The air passenger is thus considered as an important risk factor for the FMD virus entering Taiwan via meat products. In an empirical application, a logistic regression model is widely used to establish the relationship between covariates and dichotomous response (Bagely et al., 2001; Kleinbaum and Klein, 2002). The probability of intercepting passengers was predicted under different covariates such as months, origin areas, and inspection methods.

The aim of this study is to predict the risk of FMD transmission caused by passengers who illegally carry meat products of cloven-hoofed animals through international airports into Taiwan. The approach extends the previous estimation method for the probability of FMD factors via a class of statistical and probabilistic models. Moreover, the probability of the passenger event is established to be proportional to the odds of intercepting passengers. Under the validity of the proposed models, a Monte Carlo simulation was implemented to generate the likelihood values for FMD virus entering Taiwan via meat products. The study, through quantitative risk assessment, provides useful information for decision makers to make effective and efficient policy and also provides an appropriate level of protection to prevent the entry of exotic pathogens.

2. Materials and Methods

The likelihood for the risk of FMD contaminated meat products to enter Taiwan is conditional on different origin areas of passengers arriving in Taiwan. The likelihood function in this study is formulated as:

$$Likelihood\ (area) = P((FMD\ factors) \times (passenger\ event) | area) \qquad (1)$$

The FMD factors in (1) include the prevalence of FMD, denoted by N_1, the commodity factor (the contaminating virus in meat products which persists throughout processing of products), denoted by N_2, and the transportation factor (the survival of the virus in meat products after processing), denoted by N_3. The passenger event, denoted by N_4, represents non-intercepted passengers who illegally carry meat products contaminated with the FMD virus. In formulation (1), the factors of FMD virus, which persists throughout different types of treatments of meat and the survival of the virus in meat products can be reasonably set to be independent of the prevalence of FMD and the origin areas. In practice, the FMD factors are generally independent of the passenger event. By using the decomposition of the joint probability and the independent mechanism between events, the likelihood in (1) is re-expressed as:

$$Likelihood\ (area) = P(N_1|area)P(N_2 \times N_3)P(N_4|area) \qquad (2)$$

Thus, the distribution of *Likelihood(area)* can be derived via separately modeling the conditional probabilities of N_1, $N_2 \times N_3$, and N_4. To simulate the values of $P(N_1|area)$, the beta and pert distributions are applied to model the period prevalence and duration of virus viraemia. The estimated number of cloven-hoofed animals susceptible to FMD virus, the total number of cloven-hoofed animals in each country, and the minimum, median, and maximum of the duration of virus viraemia are the parameters in the considered distributions. Conditioning on different types of meat processing, the probability $P(N_2 \times N_3)$ is computed based on the conditional probability $P(N_2 \times N_3|meat)$. Moreover, $P(N_2 \times N_3| meat)$ is written as the product of $P(N_2|meat)$ and $P(N_3|meat)$ by reasonably assuming independence between the factors N_2 and N_3. By utilizing the experimental results in virus study, a class of estimation methods is proposed to derive the distribution of $P(N_2|meat)$. Based on the studies for the survival of FMD virus in meat products after processing, an appropriate probabilistic model was proposed for the conditional probability $P(N_3|meat)$. In order to compute $P(N_2 \times N_3)$, an empirical prior distribution is further used for different types of meat products. By establishing the relationship between $P(N_4|country)$ and the odds of intercepted passengers, the conditional probability of the passenger event was derived. To evaluate the effects of covariates on the probability of intercepted passengers, a widely used logistic regression analysis, which was implemented by the SAS System® Version 9.1 for Windows (SAS Institute Inc., Cary, NC, 2003) (Allison, 1999; Stokes et al., 2000) was applied in the numerical study. The values of the likelihood were repeatedly generated 10,000 times through a Monte Carlo simulation in @RISK™ (Anonymous, 2002) and Microsoft Excel™ spreadsheet software. From the empirical rule, the number 10,000 is large enough to ensure that the empirical distribution of likelihood approximates the true distribution well.

2.1. Data

The data were mainly from the records of passengers into Taiwan through the Taipei International Airport from July 2004 to June 2006. The related variables such as the month of passengers' arrival, the origin areas of meat products, and the inspection method of violating passengers by Customs or detective dogs were provided by the animal quarantine authority of the Bureau of Animal and Plant Health Inspection and Quarantine (BAPHIQ). The other information about arriving passengers was obtained from the Immigration Office, National Police Agency. The reports of FMD susceptible animals and cloven-hoofed animals from OIE (OIE, 2005) and Food Agriculture Organization (FAO, 2004; FAO, 2005) were used for analyses. After examining the violation records, the areas of origin of meat products were divided into two main areas: 1. South East Asia: Cambodia, Laos, Malaysia, Myanmar, Philippines, Thailand and Vietnam, and 2. China: Mainland China and Hong Kong (Macau). Other countries and areas are not included in this study for their relatively few violations.

2.2. Modeling the prevalence of FMD

In this section, we model the prevalence of FMD infected animals in two origin areas, i.e. $P(N_1|area)$. The computation of prevalence was mainly based on the period prevalence and the average duration of virus viraemia of FMD. To simulate the prevalence of FMD, the beta and pert distributions were separately specified for the period prevalence and the average duration of virus viraemia. In application, the beta distribution is often used to describe the uncertainty about the probability of occurrence of an event, and the pert distribution is a special form of the beta distribution. The period prevalence of each area can be expressed as Beta(x_1+1, n_1-x_1+1) where x_1 is the annual number of cloven-hoofed animals susceptible to FMD and n_1 is the total population of cloven-hoofed animals in the origin area. As for the parameters of pert distribution, the study of Sanson (1994) showed that the minimum, median, and maximum of virus viraemia are 6, 16, and 25 days. Thus, the values of $P(N_1|area)$ can be generated from the following distribution:

$$Beta\ (x_1+1,\ n_1-x_1+1)\times Pert((6,16,25)/365) \tag{3}$$

2.3. Probability of commodity and transportation factors

Probability of commodity and transportation factors can be computed via the conditional probabilities $P(N_2|meat)$ and $P(N_3|\ meat)$, and the beta prior proportion of distribution for different types of meat products contaminated with FMD virus. Beta $(x_2+1,\ n_2-x_2+1)$ was specified with x_2 being the weight of each different type of intercepted meat products and n_2 being the total weight of intercepted meat products.

The conditional probability $P(N_2|meat)$ is estimated based on the experimental results of Chou and Yang (2004) regarding the degradation rate of FMD virus in meat. According to their study, the means and standard deviations of degradation rate of FMD virus in pork sausage are 0.587 and 0.296 during the chilling procedure (2-5^{o}C for 3 days), 0.570 and 0.282 during the curing procedure (4^{o}C for 1 day), 0.170 and 0.172 during the drying procedure (initial 50^{o}C to 70^{o}C within 12 minutes and let stand for another 5 minutes), and 0.593 and 0.252 during the steaming procedure (75^{o}C for 30 minutes). Using the estimated means and standard deviations, the truncated normal distributions are specified to generate the rates of virus degradation during different meat processing methods. Since the degradation rate of FMD virus were measured at specific time points after single meat processing, the survival rate of virus at time t after the single kth treatment is estimated via the worst-case estimate

$$f_k(t) = \lambda_k, \tag{4}$$

where λ_k=1-Degradation$_k$ denotes the survival rate of FMD virus after the single kth treatment, k=1 (Chilling), 2 (Curing), 3 (Drying), and 4 (Steaming) with $\lambda_0=1$. The survival rate of virus at time t after more than one treatment is estimated via the product of the survival rates of these treatments. That is, for example, the survival rate of virus at time t after the k_1th and k_2th treatments is estimated via $f_{k_1k_2}(t) = \lambda_{k_1}\lambda_{k_2}$.

Each survival rate of virus at time t after different types of treatments is presented in Table 2. $X^{(k)}$ represents the number of viruses existing in meat after the single kth treatment. Under the validity of stationary Poisson processes for $X^{(k)}$, the probability of the virus existing in meat after the *kth* treatment can be reasonably derived as $P(X^{(k)} \geq 1) = 1 - e^{-\lambda_k}$. The probability of the virus existing in meat after more than one treatment can be derived similarly. For example, $X^{(k_1 k_2)}$ represents the number of viruses existing in meat at time t after the k_1*th* and k_2*th* treatments. The probability of the virus can be derived via $P(X^{(k_1 k_2)} \geq 1) = 1 - e^{-\lambda_{k_1} \lambda_{k_2}}$. The conditional probability $P(N_2|\ meat)$ is then estimated for different types of meat products by $P(X \geq 1)$ where X represents the number of virus existing in meat.

The transportation factor, N_3, mainly considers the survival of FMD virus after meat products leave the meat processing factory to market shelves and are carried by passengers arriving at the TPE International Airport. It indicates that N_3 consists of the transportation time of contaminated meat products (*r*) and the intrinsic survival time of FMD virus in meat products (*T*). In this study, the lognormal distribution *lognormal*(μ,σ) was used to estimate transportation time *r*, where the mean μ and standard deviation σ can be derived through the mode of transportation time and expiry times of meat products. Based on disciplining opinion, the mode and expiry times are 3 and 10 days for chilling meat, 3 and 15 days for curing meat, and 10 and 30 days for drying and steaming meat, respectively. The curing meat is the meat after chilling and curing processes. Similarly, the drying meat is the meat after chilling, curing and drying processes. Moreover the steaming meat is the meat after chilling, curing, drying and steaming processes. From the empirical distributions of transportation time for different types of meat products carried by passengers, the lognormal distribution was shown to be appropriate. As for the survival time of FMD virus in meat products, the exponential distribution Exp(t_u) was proposed, where t_u was the mean survival time. A pert distribution was further specified to generate the possible values of t_u. From the analyses of Farez and Morley (1997) and DEFRA (2003), the survival time of FMD virus in meat products ranges from 1 day to 190 days. The minimum, median, and maximum days are 1, 10, and 30 days for chilling meat, 1, 30, and 60 days for curing meat, 1, 112, and 182 days for drying meat and 1, 112, and 190 days for steaming meat. These summary statistics were used as the parameters in the pert distribution to generate the possible values of t_u. Based on the model construction for the above processes, $P(N_3|meat)$ is computed as

$$P(T > r) = \int_{r}^{\infty} \frac{1}{t_\mu} e^{-\frac{s}{t_\mu}} ds = e^{-\frac{r}{t_\mu}}. \qquad (5)$$

2.4. Probability of the passenger event

Since the information about non-intercepted passengers, who illegally carry cloven-hoofed meat products, is not available in the collected data, a more flexible relationship between $P(N_4|area)$ and the probability of non-intercepted passengers is further made. To clarify succeeding statements, some concise notations are introduced first. Let D and E denote separately the indicator of passengers intercepted ($D=1$) versus those non-intercepted ($D=0$) and the status of passengers who carry ($E=1$) versus those who do not carry ($E=0$) meat products contaminated with FMD virus. For the conditional probability $P(N_4|area)$, i.e. $P(D=0,E=1|area)$, it is reasonable to set the ratio of $P(D=0, E=1|area)$ and $P(D=0,E=0|area)$ proportional to the odds, say, $\theta\left(\text{area}\right)=\dfrac{P(D=1\,|\,area)}{P(D=0\,|\,area)}$ of $\{D=1\}$ versus $\{D=0\}$. The relationship is expressed as

$$\frac{P(D=0,E=1|area)}{P(D=0,E=0|area)}=\alpha\cdot\theta(area)\,, \tag{6}$$

where the multiplier α is a non-negative constant and can be substituted by the empirical value, say, $\hat{\alpha}$. From model (6), one can derive that

$$P(D=0,E=1\,|\,area)=\frac{\alpha\theta(area)}{(1+\theta(area))(1+\alpha\theta(area))}\quad. \tag{7}$$

It is derived from (7) that $P(D=0, E=1|area)$ is an increasing function of α, which indicates the status of inspection at the TPE International Airport. As for the odds function $\theta(area)$, two other important variables, which include the month (*mon*) of study period and the inspection (*ins*) are considered. A widely used logistic regression analysis was applied to model $P(D=1|mon, ins, area)$ as below

$$P(D=1\,|\,mon,ins,area)=\frac{\exp(\beta_0+\Sigma_{j=1}^{11}\beta_{1j}\delta_j(mon)+\beta_2 ins+\beta_3 area)}{1+\exp(\beta_0+\Sigma_{j=1}^{11}\beta_{1j}\delta_j(mon)+\beta_2 ins+\beta_3 area)}\ , \tag{8}$$

where β_l 's are the effects of the corresponding variables, and $\delta_j(mon)=1$ if *mon*=j and 0 otherwise, the variable *ins* is defined to be 1 if the meat products are intercepted by beagle and 0 otherwise, and the variable *area* is given by 1 if passengers come from China and 0 otherwise. In the above model, December is treated as the reference month. Based on the data $\{(D_i,\ mon_i,\ ins_i,\ area_i):\ i=1,\cdots,n\}$, where n is the sample size, and the logistic regression model (8), the maximum likelihood estimates, say, $(\hat{\beta}_0,\hat{\beta}_{11},\cdots,\hat{\beta}_{111},\hat{\beta}_2,\hat{\beta}_3)$ for $(\beta_0,\beta_{11},\cdots,\beta_{111},\beta_2,\beta_3)$ can be obtained. The probability $P(D=1|mon,\ ins,\ area)$ is then estimated by $\hat{P}(D=1\,|\,mon,ins,area)$

with $(\hat{\beta}_0, \hat{\beta}_{11}, \cdots, \hat{\beta}_{111}, \hat{\beta}_2, \hat{\beta}_3)$ substituting for $(\beta_0, \beta_{11}, \cdots, \beta_{111}, \beta_2, \beta_3)$. By using the empirical probability $\hat{P}(mon = i, ins = j \mid area), i = 1, \cdots, 12; j = 0, 1$, $P(D=1|area)$, and $\theta(area)$ are computed via

$$\hat{P}(D = 1 \mid area) = \Sigma_{i=1}^{12} \Sigma_{j=0}^{1} \hat{P}(D = 1 \mid mon = i, ins = j, area) \hat{P}(mon = i, ins = j \mid area) \quad (9)$$

and

$$\hat{\theta}(area) = \frac{\hat{P}(D = 1 \mid area)}{1 - \hat{P}(D = 1 \mid area)}. \quad (10)$$

To simulate the values of $P(N_4|area)$ in (7), the pert distribution is specified with 0.5, 1, and 2 assigned for the multiplier α and the odds function $\theta(area)$ being substituted by the estimate $\hat{\theta}(area)$ in (10). That is, we use the Pert($0.5\hat{\theta}(area)$, $\hat{\theta}(area)$, $2\hat{\theta}(area)$) to simulate the value of $P(N_4|area)$.

3. Results

In the numerical study, there are 9,310,011 passengers who arrived in Taiwan through the TPE International Airport during the study from July 2004 to June 2005. A total of 3,399 passengers (violation risk: 3.65×10^{-4}) illegally carrying meat products of cloven-hoofed animals were intercepted in this period. Among 2,104,261 South East Asia passengers and 4,381,854 China passengers, the violation numbers are 1,838 (violation risk: 8.73×10^{-4}) and 882 (violation risk: 2.01×10^{-4}), respectively. From the records, there were 1,778 and 942 violating passengers intercepted separately by beagles from 567,148 passengers and Customs from 5,918,967 passengers. The data of 9,877,124 passengers who arrived in Taiwan through the TPE International Airport during the study from July 2005 to June 2006, are also considered. A total of 7,345 passengers (violation risk: 7.44×10^{-4}) illegally carrying meat products of cloven-hoofed animals were intercepted. Among 1,966,333 South East Asia passengers and 4,219,041 China passengers, the violation numbers are 3,651 (violation risk: 1.86×10^{-3}) and 2,210 (violation risk: 5.24×10^{-4}), respectively. There were 4,554 and 1,307 violating passengers intercepted separately by beagles from 959,048 passengers and Customs from 5,226,326 passengers.

For the FMD factors conditioning on two origin areas, the prevalence $P(N_1|area)$

was first simulated from the proposed distribution in (3) with the number of cloven-hoofed animals susceptible to FMD (x_1) and the total number of animal population (n_1) provided in Table 1. Under different types of meat processing, the possible values of $P(N_2 \times N_3 \,|meat)$ were generated from the probabilities $P(X \geq 1)$ and (5). The parameters in the probabilistic models are estimated using the numerical results obtained from the virus experiments in Table 2. Details of the classification for meat products can be also found below this table.

Probability of the passenger event was simulated using the relation between $P(N_4|area)$ and the odds $\theta(area)$ in (7). Under the validity of the logistic regression model in (8), $P(D=1|mon, ins, area)$ was estimated as

$$Logit\hat{P}(D=1|\,mon,ins,area) = -7.53 + \Sigma_{j=1}^{11}\hat{\beta}1j_{1_j}\delta\, j(mon) - 1.26area + 2.60ins. \qquad (11)$$

The effects of the variables *ins* and *area* on the probability are significant with p-value <0.001 (Table 3). Moreover, the probability of intercepted passengers in January, February, March and April are significantly greater than in December. However, probabilities in other months are not significantly different from that in December. From the residual analysis and the Pearson chi-square test for the goodness of fit, the fitting model is shown to be appropriate. The odds of intercepting passengers by beagle and Customs range separately from 5.20×10^{-3} to 8.60×10^{-3} and 0.21×10^{-3} to 0.37×10^{-3} for passengers from South East Asia, and range from 0.30×10^{-3} to 2.15×10^{-3} and 0.09×10^{-3} to 0.19×10^{-3} for passengers from China in different months from July 2004 to June 2005. Furthermore The odds of intercepting passengers by beagle and Customs range separately from 4.53×10^{-3} to 12.4×10^{-3} and 0.26×10^{-3} to 0.85×10^{-3} for passengers from South East Asia, and range from 0.92×10^{-3} to 4.44×10^{-3} and 0.09×10^{-3} to 0.80×10^{-3} for passengers from China in different months from July 2005 to June 2006. The odds of intercepting passengers from South East Asia are 3.5 times ($e^{1.26}$) higher than that of China passengers. The odds of intercepting passengers by beagle is about 13.5 times ($e^{2.6}$) higher than the odds of passengers by Customs. The results for the empirical probability $\hat{P}(mon = i, ins = j\,|\,area), i = 1,\cdots,12;\ j = 0,1$ are shown in Table 4. The derived estimates $\hat{\theta}(area)$ are 1.42×10^{-3} and 3.48×10^{-4} for South East Asia and China, respectively. The probabilities of the passenger event are then computed from the pert distributions: Pert (7.09×10^{-4} (α=0.5), 1.42×10^{-3} (α=1), 2.83×10^{-3} (α=2)) for South East Asia and Pert (1.74×10^{-4} (α=0.5), 3.48×10^{-4} (α=1), 6.95×10^{-4} (α=2)) for China.

By implementing 10,000 iterated simulations, the results in Table 5 show that the median value of the likelihood for FMD virus risk caused by FMD factors from China

(1.01×10^{-5}) was close to that from South East Asia (1.17×10^{-5}). However, the likelihood for FMD virus risk caused by the passenger event from China (3.69×10^{-4}) was lower than that caused by passengers from South East Asia (1.51×10^{-3}). In total, the likelihood of FMD virus risk entering Taiwan through air passenger violations at the TPE International Airport from China (3.65×10^{-9}) was significantly lower than that from South East Asia (1.73×10^{-8}).

4. Discussion

It is well recognized that FMD virus is likely to be present in meat from animals that were viraemic at the time of slaughter, and the duration of survival of virus in meats usually depends on certain factors (Pharo, 2002). Based on experimental results and disciplining opinion in this study, a class of flexible and easily explained models was proposed to characterize the likelihood for FMD transmission caused by passengers who illegally carry meat products through TPE International Airport into Taiwan.

The study retrieves heads of cloven-hoofed animals affected by the FMD virus and their corresponding animal population at risk in five years according to OIE reports to calculate the prevalence of FMD for the predictive model. The available information about the number of susceptible animals and the number of reported FMD cases in China was mainly from Beijing, Gansu, Hebei, Jiangsu, Qinghai, Shandong, Xinjiang (Sinkiang) and Yanqing, province (city) and autonomous region, between May and July of 2005 and also from Hong Kong data for the past 5 years. Since no other informative reports were accessible, the estimation risk is thus not precise enough. Future promising estimations can be predicted if information from China is openly shared.

As for the commodity factor, the experimental results of a pork sausage study (Chou and Yang, 2004) were used to estimate the probability of virus existence in meat products after processing. The virus survival rate at time t was estimated using the product of the rates of virus degradation of all successive meat treatments. We use the worst-case estimate to evaluate the risk. Of course, the risk of this part is over-estimated in the model. However, it is better for us to use over-estimated risk without further information. It makes us pay attention to the disease. The model can be developed further through better close follow-up experiments or related information. An empirical probability distribution was specified based on the records of intercepted meat products.

As for likelihood values of the transportation factor, a lognormal distribution with the right-skewed characteristics was considered to predict the transportation time (r) of meat products since it is usually carried by passengers in fresh meat. Instead of computing the survival time of FMD virus in meat products $P(T>0)$, the probability $P(T>r)$ takes into account the survival time of FMD virus in meat products after passengers arriving in Taiwan. An exponential distribution was used to characterize the survival time of FMD virus in meat products. This distributional assumption can be generalized to some other parametric distributions such as the Weibull distribution, the gamma distribution, etc., or the empirical distribution if certain experiments related to the survival time of FMD virus in meat products can be conducted.

Apart from using the logistic regression model to predict the probability of intercepted passengers, the other models such as the probit model, the complementary log model, and the complementary log-log models may provide very similar explanations. When the multiplier α was set at 1, the odds of intercepting passengers is the same as the ratio of probability of non-intercepting passengers carrying meat products contaminated with FMD virus and non-intercepting passengers who do not carry meat products contaminated with FMD virus. Thus, the setting of the values of α can show whether quarantine measures were effectively and strictly implemented.

Based on risk analysis, it was shown that the odds of intercepted passengers from South East Asia were about 3.5 times higher than those from China. Furthermore, the likelihood value for the risk of FMD caused by FMD factors in China was close to that in South East Asia. The likelihood value for the risk of FMD transmission into Taiwan from China after Monte Carlo simulations was then significantly lower than that from South East Asia. It is reasonable to recommend authorities to strengthen inspection of passengers from China and South East Asia in the high-risk months (January–April) and also enhance the beagle inspection system.

5. Conclusions

The socio-economic aspects of a country can be impacted by FMD in the international trade of animals and animal products. The above mentioned two areas, China and South East Asia, may pose a potential risk of FMD outbreak in Taiwan through air-passenger violations. Thus, our results are a novel contribution to FMD prevention and may provide decision makers with significant data to help decrease the introduction of animal diseases into their country.

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Table 1

Data of FMD susceptible animals and population of cloven-hoofed animals in two main areas.

Area	Origin Country	FMD susceptible animals (heads)	Population of cloven-hoofed animals (heads)
China	Hong Kong[a]	12,881	1,784,769
	Mainland China[b]	4,653	4,673,160
South East Asia[a]	Cambodia	18,121	4,607,943
	Laos	39,522	2,138,320
	Malaysia	19,837	2,040,619
	Myanmar	57,194	12,657,736
	Philippines	20,835	9,363,730
	Thailand	142,399	10,258,926
	Vietnam	2,323	21,870,258

[a] Average heads (2000-2004).

[b] Province (city) and autonomous region: Beijing, Gansu, Hebei, Jiangsu, Qinghai, Shandong, Xinjiang (Sinkiang), and Yanqing (May and Jul. 2005).

Table 2

Survival rate of FMD virus and illegally carried meat products intercepted at CKS International Airport.

Types of meat	Survival Rate [a]	Intercepted Meat (Kg)[c,] (x_2) [d]	
	f(t)	China	South East Asia
Chilling	λ_1=1-TN[b] (0.587±0.296)	28.6	12.5
Curing	$\lambda_1\lambda_2=\lambda_1$ (1- TN(0.570±0.282))	4.3	14.3
Drying	$\lambda_1\lambda_2\lambda_3=\lambda_1\lambda_2$ (1- TN(0.170±0.172))	2138.9	1337.4
Steaming	$\lambda_1\lambda_2\lambda_3\lambda_4=\lambda_1\lambda_2\lambda_3$ (1-TN(0.593±0.252))	1350.6	5780.7

[a] Experiment results from Chou and Yang (2004).

[b] Truncated normal distribution.

[c] Chilling: chilled meat;
Curing type: meatball, steak, etc..
Drying: Jerky, dried meat, etc..
Steaming: ham, Chinese Ham, hot dog, bacon, sausages, meat stuffing, etc..

[d] n_2: total intercepted meat weight (China: 3,522.4 kg, South East Asia: 7,144.9 kg).

Table 3

The parameter estimates and odds of intercepted passengers by months, origin areas, and inspection methods during years 2004 and 2006.

Estimates		Odds[a]							
Month	$\hat{\beta}_{1j}$	SEA[b] and Customs		SEA[b]and Beagle		China and Customs		China and Beagle	
		Year1[d]	Year2[e]	Year1[d]	Year2[e]	Year1[d]	Year2[e]	Year1[d]	Year2[e]
Jul.	-0.6103	0.36	0.28	5.26	4.53	0.10	0.07	0.62	1.13
Aug.	-0.5311	0.26	0.41	5.20	4.88	0.14	0.11	0.55	0.92
Sep.	-0.6385	0.21	0.26	6.38	7.67	0.08	0.09	0.30	1.49
Oct.	-0.4452	0.29	0.30	5.50	7.13	0.12	0.09	0.40	2.81
Nov.	-0.0066	0.33	0.64	7.71	7.15	0.12	0.30	1.07	3.29
Dec.	-[c]	0.26	0.76	5.84	8.66	0.14	0.33	1.03	3.32
Jan.	0.2551	0.29	0.65	7.90	11.8	0.19	0.80	1.15	3.92
Feb.	0.1903	0.28	0.59	7.23	12.4	0.17	0.29	2.15	4.44
Mar.	0.0121	0.23	0.71	7.94	11.6	0.11	0.21	1.55	3.29
Apr.	0.0131	0.34	0.85	8.60	9.07	0.11	0.29	1.41	1.73
May	-0.1807	0.30	0.55	6.25	7.01	0.09	0.23	1.21	1.92
Jun.	-0.2108	0.37	0.48	7.21	5.44	0.10	0.12	1.59	2.20

$Logit\hat{P}\left(D=1 \mid mon, ins, area\right) = -7.53 + \Sigma_{j=1}^{11}\hat{\beta}_{1j}\delta_{j}(mon) - 1.26area + 2.60ins$.

[a] $\times 10^{-3}$.

[b] South East Asia.

[c] Reference month.

[d]Year1: 2004/07~2005/06

[e]Year2: 2005/07~2006/06

Table 4

The empirical probability $\hat{P}(mon = i, ins = j \mid area), i = 1, \cdots, 12; j = 0, 1$.

Month	Empirical Probability[a]			
	SEA[b] and Customs	SEA[b]and Beagle	China and Customs	China and Beagle
Jul.	8.53	1.14	8.40	0.81
Aug.	8.73	1.20	8.19	0.84
Sep.	7.37	0.85	7.18	0.84
Oct.	6.81	1.17	7.53	0.81
Nov.	6.10	1.08	6.39	0.95
Dec.	6.41	1.08	6.62	0.86
Jan.	6.05	1.01	6.53	1.28
Feb.	7.93	1.49	7.28	0.98
Mar.	6.64	1.72	7.13	1.28
Apr.	6.92	1.57	8.02	1.30
May	6.96	1.79	7.48	1.36
Jun.	5.37	2.08	6.68	1.23

[a] $\times 10^{-2}$.

[b] South East Asia.

Table 5

Simulated values for FMD factors, passenger event, and likelihood for the risk of FMD contaminated meat products to enter Taiwan.

Area	Factors/Event/*Likelihood*	5th percentile	Median	95th percentile
China	Prevalence of FMD	7.31×10^{-5}	1.19×10^{-4}	1.62×10^{-4}
	Commodity and transportation	2.91×10^{-2}	8.88×10^{-2}	1.96×10^{-1}
	FMD factors	3.13×10^{-6}	1.01×10^{-5}	2.51×10^{-5}
	Passenger event	2.32×10^{-4}	3.69×10^{-4}	5.45×10^{-4}
	Likelihood (α=0.5)	5.45×10^{-10}	1.76×10^{-9}	4.36×10^{-9}
	Likelihood (α=1)	1.09×10^{-9}	3.51×10^{-9}	8.72×10^{-9}
	Likelihood (α=2)	2.18×10^{-9}	7.03×10^{-9}	1.74×10^{-8}
	Likelihood (China)	1.05×10^{-9}	3.65×10^{-9}	9.98×10^{-9}
South East Asia (SEA)	Prevalence of FMD	1.28×10^{-4}	2.08×10^{-4}	2.84×10^{-4}
	Commodity and transportation	1.77×10^{-2}	5.85×10^{-2}	1.43×10^{-1}
	FMD factors	3.30×10^{-6}	1.17×10^{-5}	3.14×10^{-5}
	Passenger event	9.45×10^{-4}	1.51×10^{-3}	2.21×10^{-3}
	Likelihood (α=0.5)	2.34×10^{-9}	8.33×10^{-9}	2.23×10^{-8}
	Likelihood (α=1)	4.68×10^{-9}	1.67×10^{-8}	4.46×10^{-8}
	Likelihood (α=2)	9.36×10^{-9}	3.33×10^{-8}	8.93×10^{-8}
	Likelihood (SEA)	4.51×10^{-9}	1.73×10^{-8}	5.18×10^{-8}

計畫成果自評

The socio-economic aspects of a country can be impacted by FMD in the international trade of animals and animal products. Up to present, there is no publishable prediction model applying in air-passenger violations apart from our first publication in Preventive Veterinary Medicine 68: 115-112, 2005. Based on experimental results and disciplining opinion in this study, we proposed a class of flexible and easily explained models to characterize the likelihood for FMD transmission caused by passengers who illegally carry meat products through TPE International Airport into Taiwan. The mentioned two areas, China and South East Asia, may pose a potential risk of FMD outbreak in Taiwan through air-passenger violations. Thus, our results are a novel contribution to FMD prevention. Our proposed models can not only achieve an appropriate level of protection to prevent the entry of foreign pathogens but also benefit the goal of transparency in risk management that can assist animal-quarantine authorities in their evaluation the effectiveness of current and alternative prevention and control strategies, as well as infrastructure and resource requirements. The design and information once published will be shared worldwide and support a better strategy to prevent a pandemic FMD outbreak.

出席國際學術會議心得報告

計畫編號	NSC 95-2313-B-002-057
計畫名稱	機場旅客違規攜入動物產品傳入口蹄疫風險模式研究
出國人員姓名 服務機關及職稱	周晉澄 教授　國立台灣大學獸醫學系
會議時間地點	3-6 June, 2007. Hong Kong
會議名稱	5th International Conference on Marine Pollution and Ecotoxicology
發表論文題目	Persistent organic pollutants in cetaceans of Taiwan waters

一、　參加會議經過

本次會議 2007 年 6 月 3-6 日在香港城市大學舉行，由該大學的生物與化學系主辦。除了開幕式在該校大會議演講廳舉行外，其他專題報告、口頭報告在四個會議室及海報專區舉行。與會者來自中國、香港、澳門、台灣、挪威、新加坡、馬來西亞、巴基斯坦、科威特、美國、日本、澳洲、英國、加拿大、義大利、韓國、法國、菲律賓、南非、西班牙、葡萄牙、伊朗、印度、德國、巴西、俄國、摩洛哥、波蘭、坦桑尼亞、斯洛文尼亞，超過三十個國家近三百人與會。

6 月 3 日報到註冊、看板報告開始陳列及會前認識宴會等活動揭開序幕。6 月 4 日早上為開幕式，由本會議主席香港城市大學生物與化學系主任 Rudolf S.S.Wu 教授主持，並有香港城市大學副校長 David Tong 教授與香港政府環境運輸與工作部執行秘書 Sarah Liao 博士致詞。在茶點招待休息後

緊接著四場專題報告，重點為新發生的環境污染物的偵測與趨勢、汞之長時性海洋生態污染偵測分析、水生基質快速有效的品質評估及利用肝膽上皮細胞分析正常與毒性反應。最後依貧氧與優養化、污染偵測與修補、生態毒理與風險評估三個主題在三間會議室中進行口頭報告與討論。當日結束後安排主辦系所之實驗室參訪。

6月5日安排了四場專題報告，重點內容為長效性有機污染物之量測與風險評估、類醇類與環境中雌體素之因果、南中國海岸鯨豚類與水鳥蛋的長效性有機污染物污染層級與亞太溴化物污染分析。之間則依四個主題在四間會議室中進行口頭報告與討論，其分別是貧氧與優養化、污染偵測與修補、生態毒理與風險評估及長效性有機污染物與內分泌激素干擾物。結束後在 The Royal Garden Hotel 安排大會正式晚宴。

6月6日安排二場專題報告，重點內容為利用暴露時間與生存預測模式分析水生生物毒性及以 Bayesian 技術增進海洋生態風險評估決策。接著依六個口頭報告主題在四間會議室中進行討論，其分別為海洋中關心的化學物質、貧氧與優養化、污染偵測與修補、生態毒理與風險評估、海洋污染相關新技術發展及長效性有機污染物與內分泌激素干擾物。大會最後在頒發學生參與得獎後閉幕。

二、　與會心得

首先最令我驚訝，是一個並非香港第一流大學的一個學系所主辦的國際性會議，竟然能夠吸引三十多個國家近三百名學者與會。而這個會議同時也

引起國際學術界的重視，其結果將登載於 SCI 國際學術期刊 Marine Pollution Bulletin 中。

到底有什麼特殊的原因？我個人認為，除了香港過去在封閉的中國與國際的接軌開放中扮演的角色外，也由其因產業企業與工業污染的轉移，圖顯出特別的比較研究價值，而能讓越來越多的海洋環境污染學者願意共聚一堂，比擬相關情境。這個情形非常值得我們思索，要以自身的體驗融入國際的關注，也就是說不可畫地自限，而且要深耕紮實發揮所長。

這個會議中，我以口頭報告發表台灣海域鯨豚遭受持久性有機污染物-多氯聯苯、DDT 之污染情形。與會日本學者 Shinsuke Tanabe 教授在專題報告中就全世界的鯨豚遭受多氯聯苯與 DDT 之污染有著非常詳細的比較分析，然而資料中獨漏台灣海域；我的報告與資料正好提供補足了相關缺憾，大家都有所得，收獲不小。

除此之外，我與國立台灣海洋大學郭教授共同發表針對台灣雄性鮭魚生殖器萎縮寡精之環境荷爾蒙污染關係探討看板論文，亦引起相關學者的興趣。同樣的污染關注亦見於如中國、韓國、日本等國家。

本次參與會議期間特別感受到中國研究生之認真學習研究精神，此與台灣學生汲汲營營不認真有著很大的差別，如果台灣的教育不再積極些，老師與學生不再努力些，過去台灣在全球學術的表現將盡失，而且中國將很快的

凌駕我們，不可不慎！

口頭報告論文摘要：

Persistent organic pollutants in Cetaceans of Taiwan waters

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The concentrations of bubbler samples of persistent organic pollutants (POPs)- including 19 polychlorinated biphenyls (PCBs), DDT, and DDE, was identified by gas chromatograph-mass spectrometry (GC/MS) in 13 Cetacean species of by-caught or stranded marine mammals in Taiwan waters. The oxidative DNA biomarker, 8-hydroxy-2'-deoxyguanosine (8-OHdG) was also determined in some of the above animals' liver and kidney samples through isotope-dilution liquid chromatography coupled with tandem mass spectrometry (LC/MS/MS). In general, the results of Pops and toxicity (measured as 2,3,7,8-tetrachlorodibenzo-*p*-dioxin equivalents, TEQs) showed that mature male animals were higher than those of immature male but inconsistency was found in female animals, and the results of stranded animals also were higher than those of by-caught animals. The above results may have influenced by animal's age, gender, species, gestation, lactation, starvation and illness status. Comparing with literature, the collected samples from Taiwan waters had relative lower Pops and TEQs than those from high-latitude areas. The level of 8-OHdG was found to be no statistical significance to the health status and species differences but had positive correlation with level of PCBs. A high correlation of TEQs to 8-OHdG was also found in mature female animals. Thus, 8-OHdG may be served as an oxidative DNA damage bio-indicator to natural exposure to environmental contaminants in female cetaceans.

看板報告論文摘要：

What inhibits the testicular development in Taiwan landlocked salmon (*Oncorhynchus masou formosanus*)?

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The Taiwan salmon (*Oncorhynchus masou formosanus*) survives as a remnant, landlocked population in the headwaters of Chichiawan Stream, a tributary of the Tachia River of central Taiwan. The existing population is estimated to be 1000 to 2000. Fish of spawning age numbered between 110 and 420. Maximum age is about 4. As a result of agricultural development, nutrient, pesticide, and trace metal concentrations are elevated in Chichiawan Stream for the past 40 years. Sex ratio in Taiwan salmon population is extreme uneven (1 female/ 0.65 male), and many matured male fish develop atrophic testes. In the environment, nonylphenol (NP) occurs predominantly as a degradation product of nonylphenol ethoxylate (NPE). They are often used as co-formulants in pesticides and biocides and these two widespread pollutants are bioconcentrated in riparian vegetation and aquatic biota of Taiwan salmon’s habitats. It is becoming evident that an increasing number of widely used industrial and agricultural chemicals are estrogenic recently. We also found that NP distributed in the organ and tissue of Taiwan salmon; NP mainly present in liver with concentration comparable with those of riparian tree leaf. These results support the contention that exposure of wildlife to environmentally persistent estrogenic chemicals can result in deleterious reproductive consequences. The concentrations and distributions of NP observed in this study are ecologically significant and may cause the major concerns for successful reproduction of wild Taiwan salmons exposed to low levels of estrogenic substances that occur from current discharges into Chichawan Stream.