STOCHASTIC DIFFERENTIAL EQUATION MODEL FOR DISEASE SURVEILLANCE

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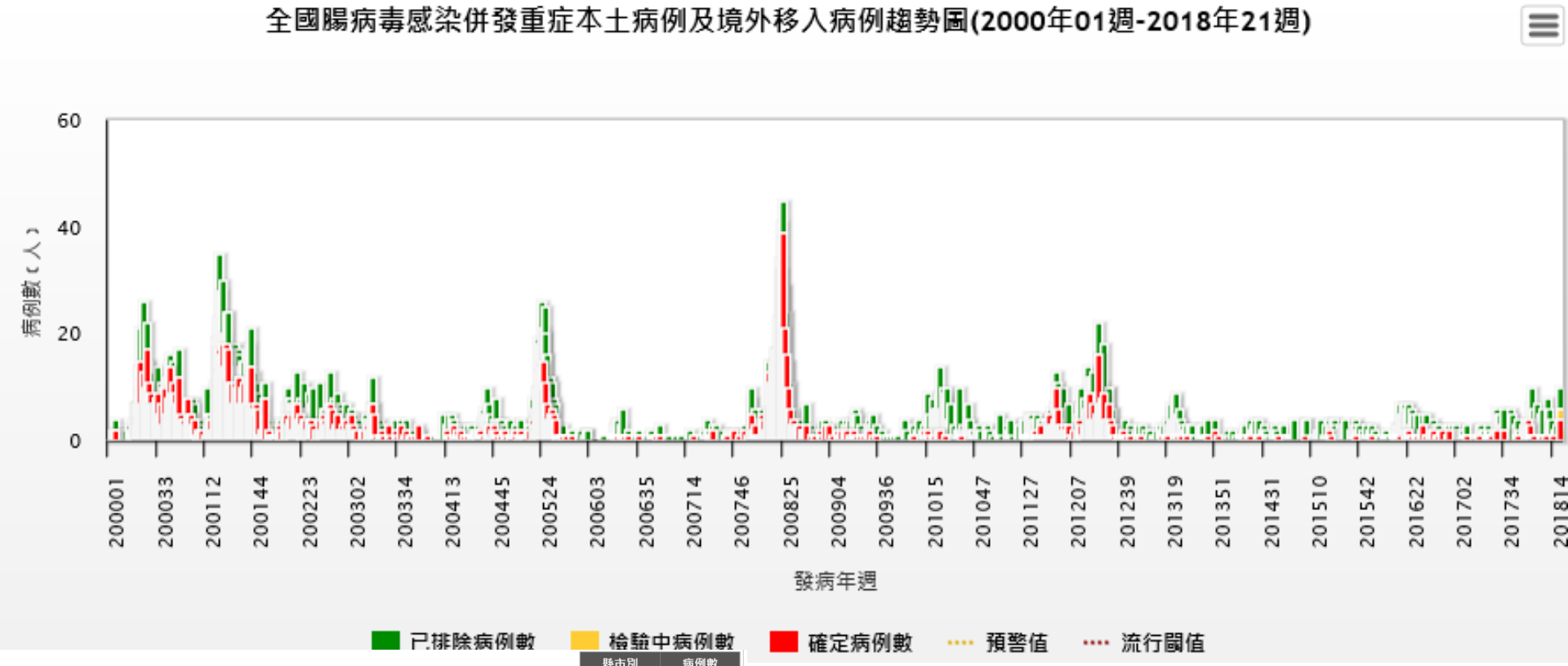
Surveillance

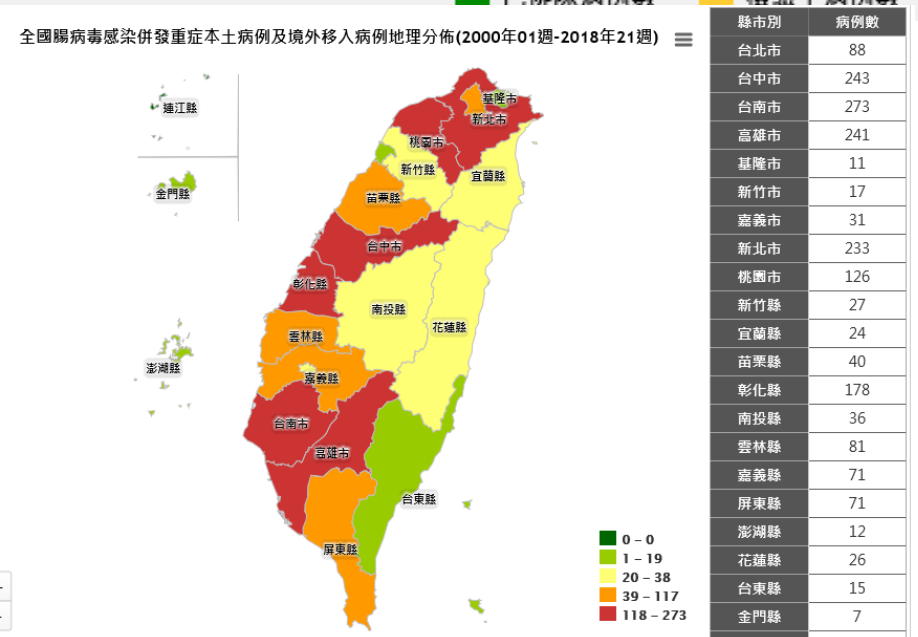
- ongoing systematic **collection**, **collation**, **analysis** and **interpretation of data** and the **dissemination of information** to those who need to know in order that **action may be taken**

- 收集，整理，分析和解釋數據

- 信息傳播給需要知道的人員

- 採取行動

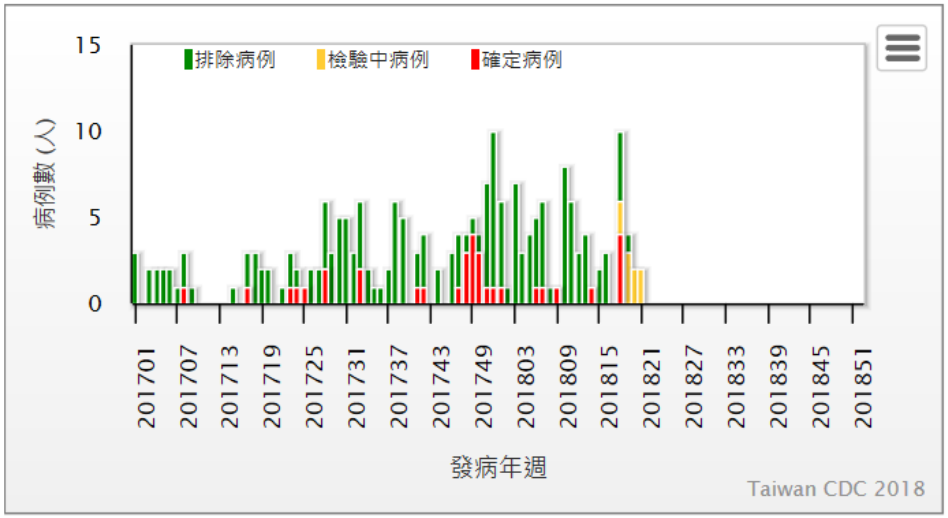




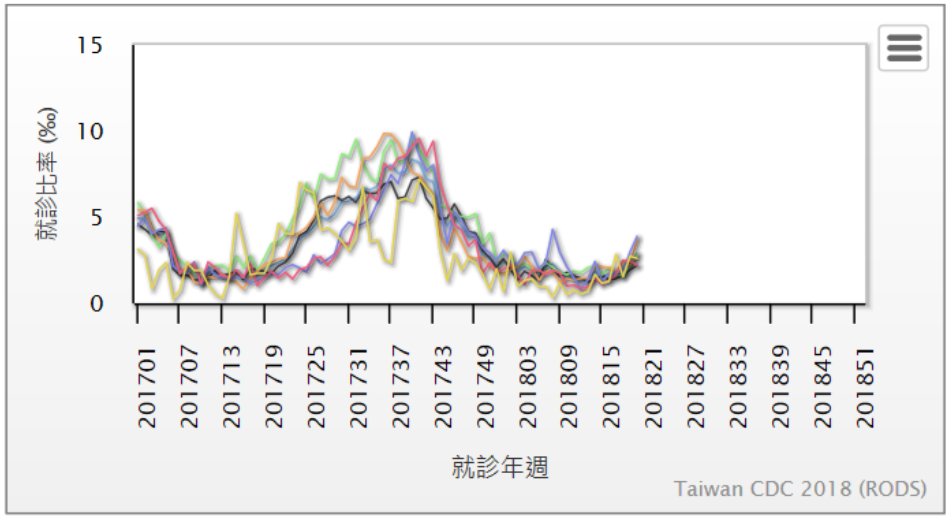
縣市別	病例數
台北市	88
台中市	243
台南市	273
高雄市	241
基隆市	11
新竹市	17
嘉義市	31
新北市	233
桃園市	126
新竹縣	27
宜蘭縣	24
苗栗縣	40
彰化縣	178
南投縣	36
雲林縣	81
嘉義縣	71
屏東縣	71
澎湖縣	12
花蓮縣	26
台東縣	15
金門縣	7

The first large outbreak of hand, foot, and mouth disease (HFMD) with severe complications primarily caused by enterovirus 71 was reported in Taiwan in 1998.

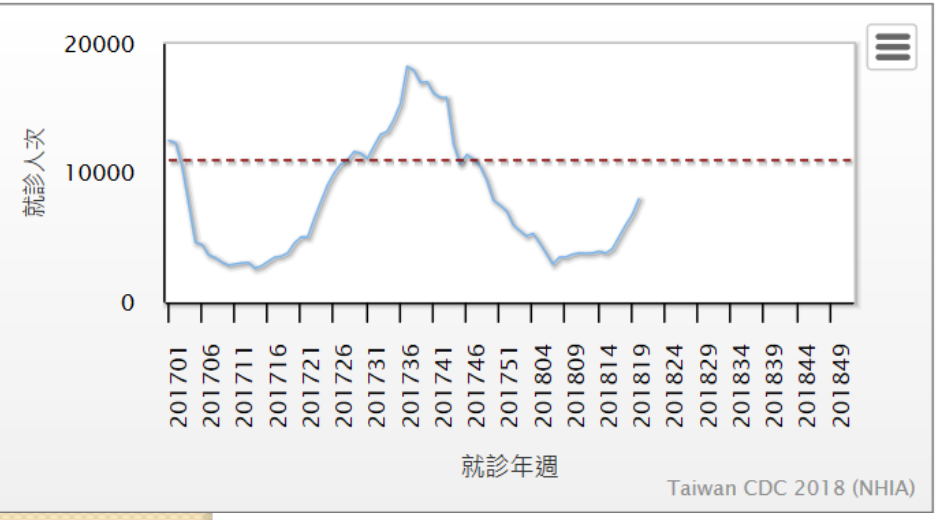
全國腸病毒感染併發重症本土及境外移入病例趨勢圖



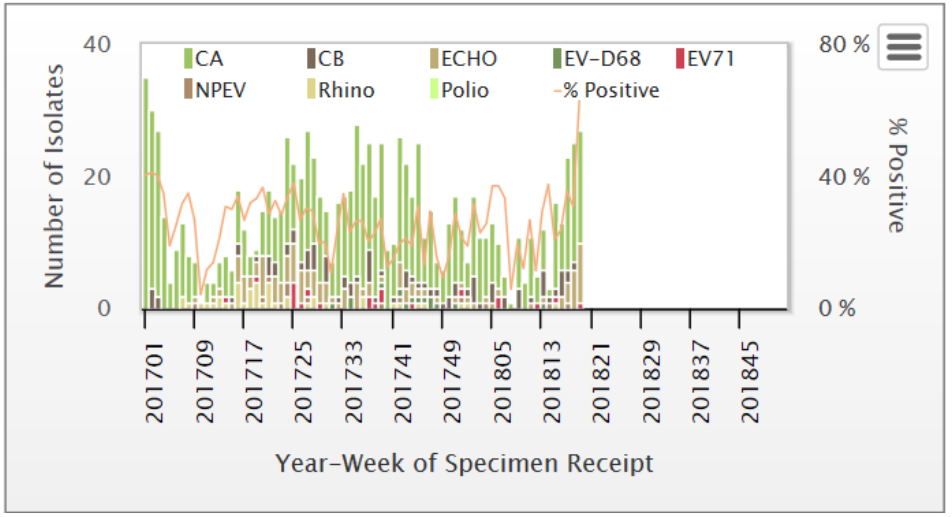
全國及各區近兩年每週急診腸病毒就診率趨勢圖



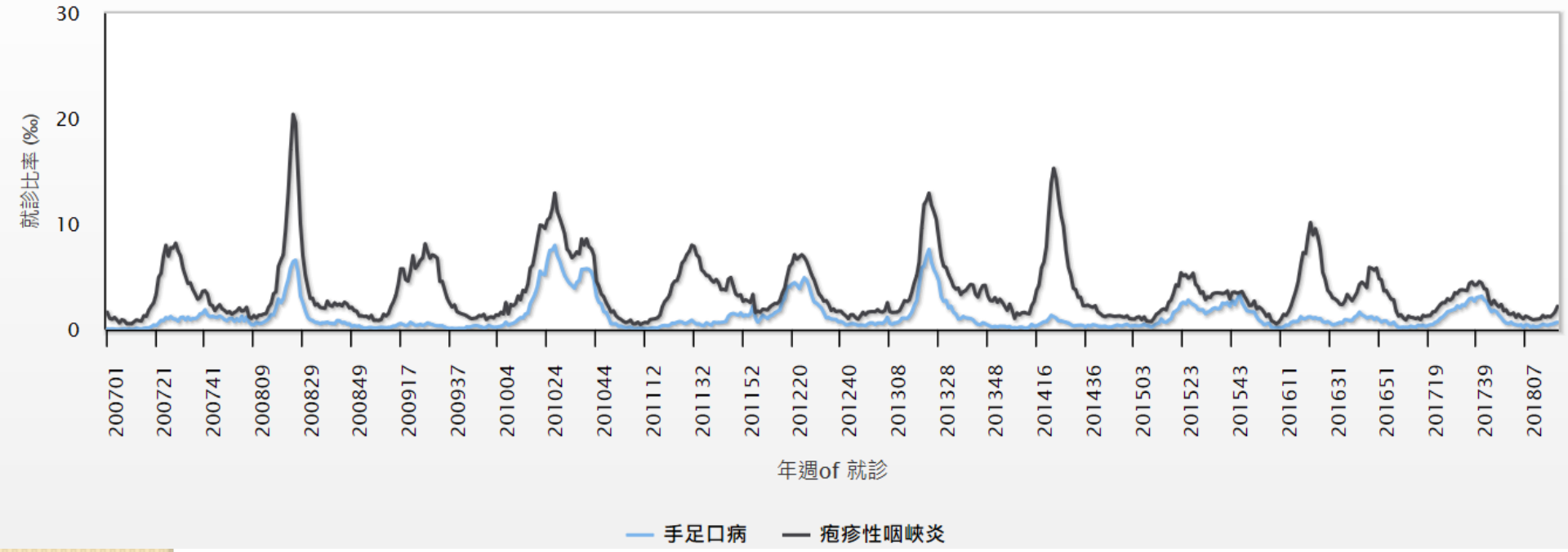
全國近兩年腸病毒健保門急診就診人次趨勢圖



全國每週腸病毒病毒分離情形



2007年01週~2018年20週全國急診手足口病和疱疹性咽峽炎每週就診千分比趨勢比較



The specific goals of Integrated Disease Surveillance and Response

- Strengthen district level surveillance and response for priority diseases,
- Integrate laboratory with laboratory support
- Reduce duplication in reporting,
- Share resources among disease control programs
- Translate surveillance and laboratory data into specific and timely public health actions.

A dynamic model for the outbreaks of hand, foot, and mouth disease in Taiwan

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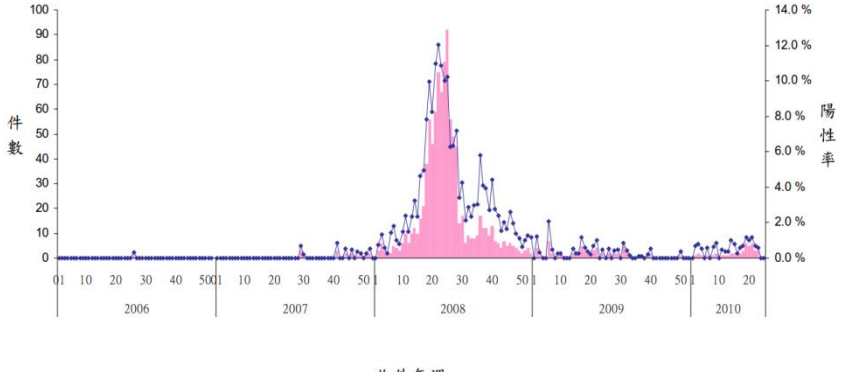
Received 21 December 2014; Final revision 5 October 2015; Accepted 7 October 2015

2006-2010年週病毒合約實驗室檢出EV71病毒型別之圖分析



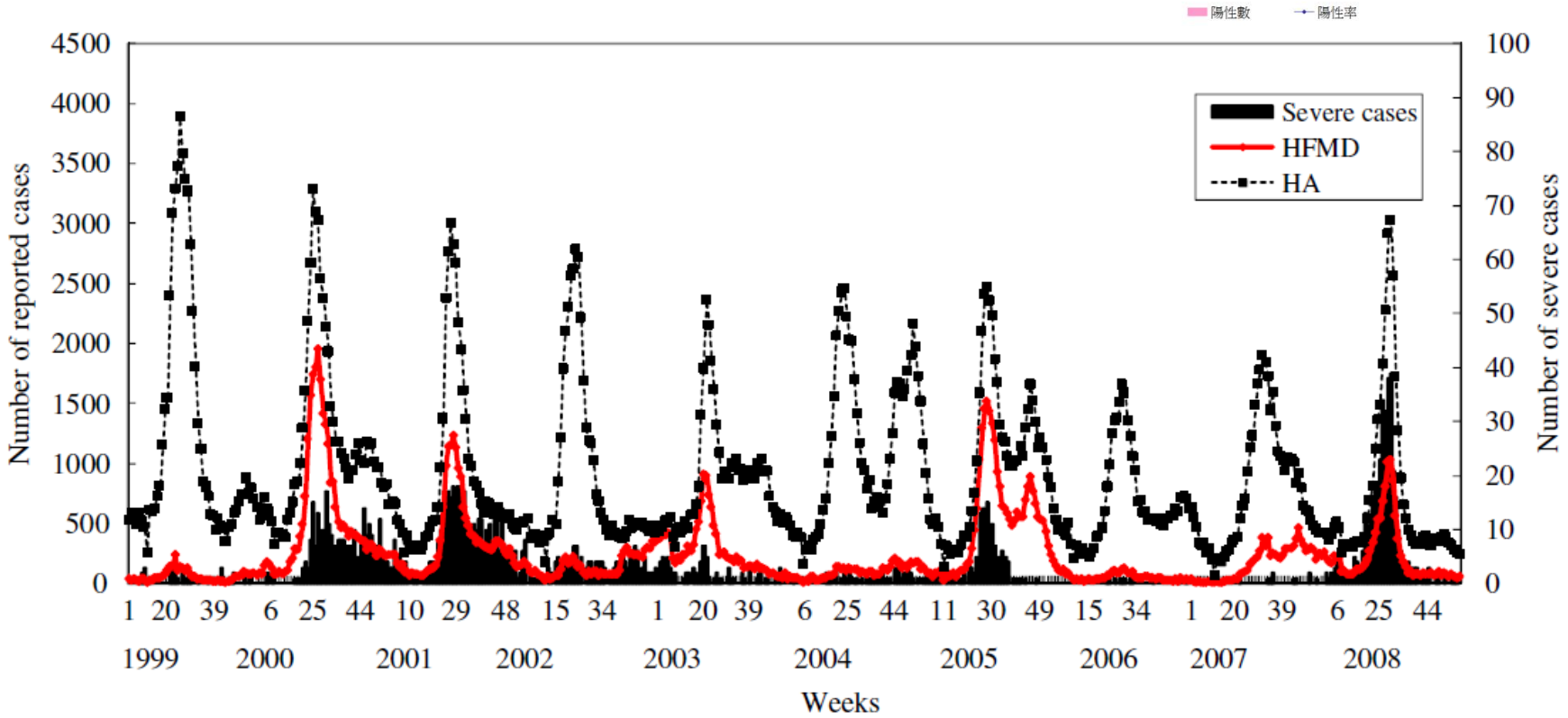


Fig. 1. The reported cases of hand, foot, and mouth disease (HFMD) or herpangina (HA) in a physician-based sentinel surveillance system and the severe cases of HFMD or HA in Taiwan from 1999 to 2008.

Natural History

$$R_0 = \frac{\beta}{\mu + \alpha} + \frac{\beta\alpha(1-\rho)}{(\mu+\alpha)(\mu+\tau_a)} + \frac{\beta\alpha\rho}{(\mu+\alpha)(\mu+\tau_s)}.$$

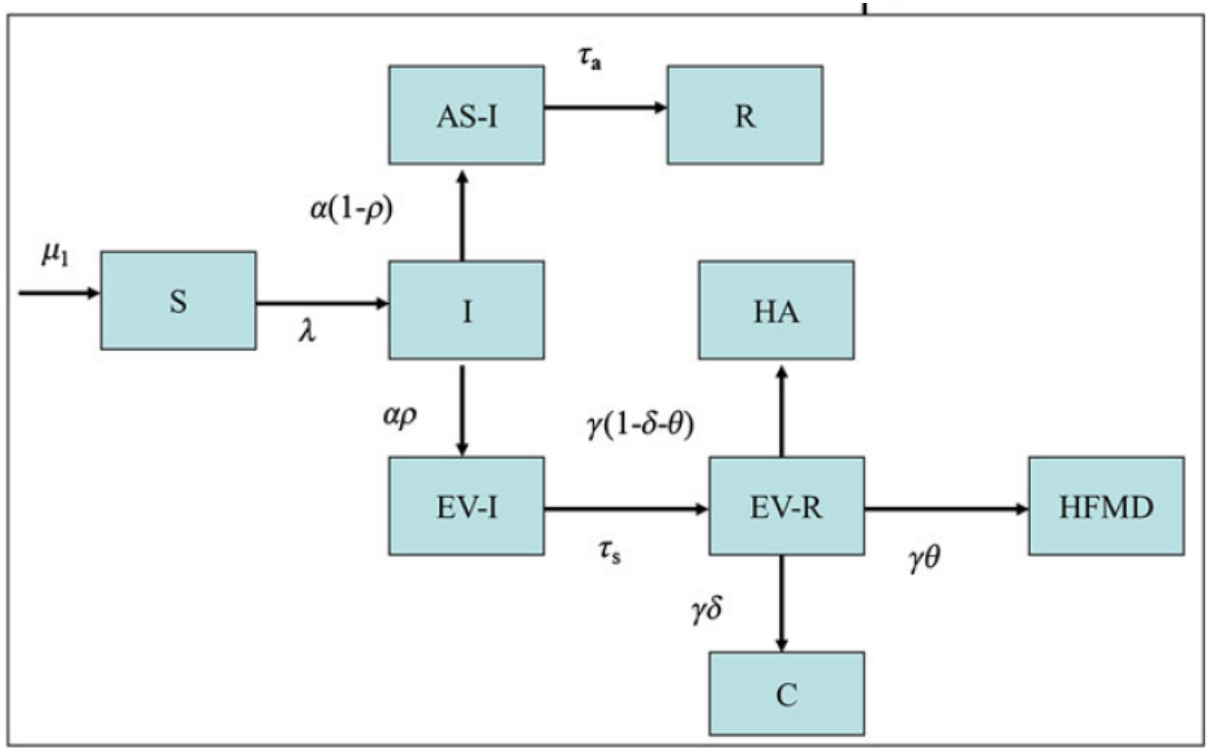


Fig. 2. HFMD model. S, Susceptible; I, infectious cases before developing symptoms; AS-I, asymptomatic cases with infectiousness; R, asymptomatic subjects with immunity after infection; EV-I, infectious cases after developing symptoms; EV-R, symptomatic cases with immunity; HA, cases with herpangina or other symptoms; HFMD, cases with hand, foot, and mouth disease; C, severe cases due to HFMD virus; μ_1, birth rate; μ, death rate; λ, force of infection; α, transfer rate from I to EV-I or AS-I; ρ, proportion of symptomatic cases; τ_a, rate of recovery from AS-I; τ_s, recovery rate from EV-I; γ, transition rate from EV-R; θ, ratio of the HFMD; δ, proportion of severe cases to all symptomatic cases with the enterovirus which result in HFMD.

Table 1. *The parameters of model for HFMD outbreaks in Taiwan*

Variable	Range	Outbreak 2000	Outbreak 2001	Outbreak 2005	Outbreak 2008	Outbreak 2008*
Parameter setting						
N	—	22 092 387	22 276 672	22 689 112	22 958 360	22 958 360
μ_1	—	$3{\cdot}8 \times 10^{-5}$	$3{\cdot}2 \times 10^{-5}$	$2{\cdot}5 \times 10^{-5}$	$2{\cdot}37 \times 10^{-5}$	$2{\cdot}37 \times 10^{-5}$
μ	—	$1{\cdot}6 \times 10^{-5}$	$1{\cdot}6 \times 10^{-5}$	$1{\cdot}7 \times 10^{-5}$	$1{\cdot}71 \times 10^{-5}$	$1{\cdot}71 \times 10^{-5}$
S	—	45%	45%	45%	45%	45%
E	—	1·4%	1·4%	1·4%	1·4%	1·4%
α	>0·167	0·35	0·35	0·35	0·35	γ(32·92, 0·01)
τ_a	0·028–0·125	0·08	0·08	0·08	0·08	γ(28·44, 0·0028125)
τ_s	0·028–0·125	0·08	0·08	0·08	0·08	γ(28·44, 0·0028125)
γ	—	1	1	1	1	1
ρ	0·47–0·94	0·7	0·7	0·7	0·7	β(0·6225, 0·26048)
θ	0·45–0·49	0·47	0·47	0·47	0·47	0·47
Infected number at beginning of outbreak	—	80	240	110	500	500

N, Number of total population; μ_1, birth rate; μ, death rate; S, proportion of susceptible; E, proportion of exposed to infectious subjects; α, transition rate from I to EV-I or AS-I; τ_a, rate of recovery from AS-I; τ_s, recovery rate from EV-I; γ, transition rate from EV; ρ, proportion of symptomatic cases; θ, ratio of HFMD; δ, proportion of severe cases; β, transmission coefficient.

* The parameters for calculating R_0 with Markov Chain Monte Carlo.

Table 2. *The results of associated parameters for model fitting the outbreaks*

Variable	Range	Outbreak 2000	Outbreak 2001	Outbreak 2005	Outbreak 2008	Outbreak 2008*
β (per day)	—	$5{\cdot}7 \times 10^{-7}$	$5{\cdot}6 \times 10^{-7}$	$4{\cdot}5 \times 10^{-7}$ (<34 weeks) $1{\cdot}2 \times 10^{-6}$ ($\geqslant$34 weeks)	$5{\cdot}3 \times 10^{-7}$ ($\leqslant$25 weeks) 2×10^{-7} (25–33 weeks) 4×10^{-7} ($\geqslant$34 weeks)	Inverse gamma (2·00, $5{\cdot}85 \times 10^{-7}$)
δ (per day)	0–0·21	0·0018	0·0023	0 (<24 weeks) $6{\cdot}75 \times 10^{-4}$ (24–32 weeks) $1{\cdot}35 \times 10^{-4}$ (>32 weeks)	0·0036	0·0036
Proportion of cases reported	—	25%	22%	22·5%	22%	22%
Predicted severe cases (reported cases)	—	365·38 (367)	403·7 (395)	66·63 (57)	373·52 (373)	—
R_0	—	1·22	1·21	1·59	1·18	1·37 (95% CI 0·23–5·71)

δ, Proportion of severe case; β, transmission coefficient; CI, confidence interval.
* The results in sensitivity analysis after 15 000 times sampling simulation.

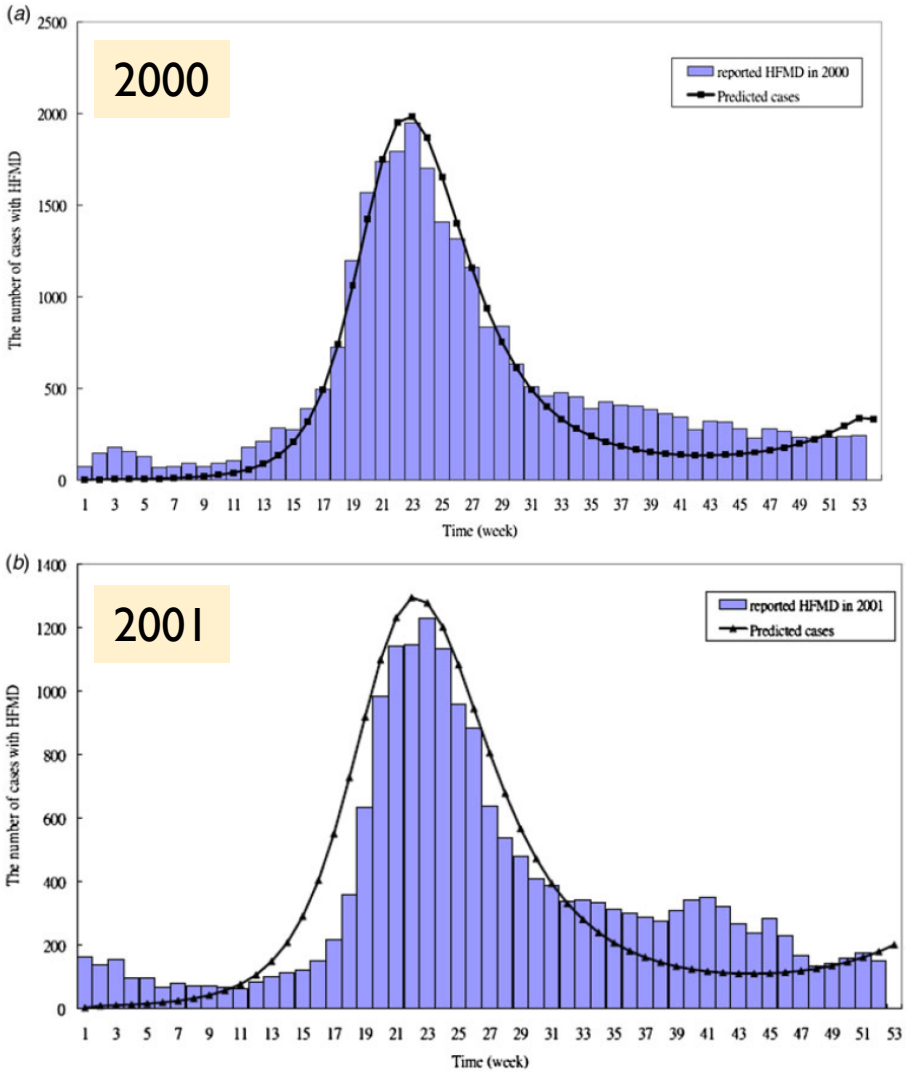


Fig. 3 (*a*, *b*). The observed and predicted HFMD cases in Taiwan in (*a*) 2000; (*b*) 2001.

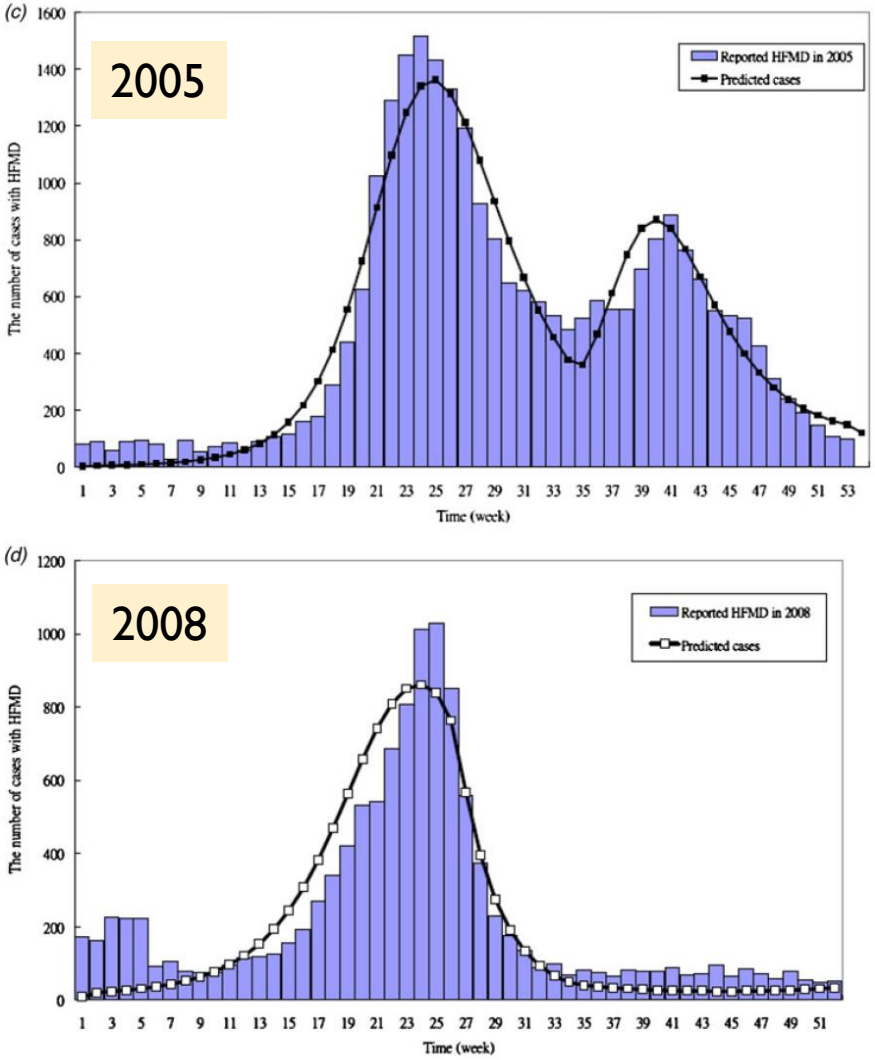


Fig. 3 (*c*, *d*). The observed and predicted HFMD cases in Taiwan in (*c*) 2005; (*d*) 2008.

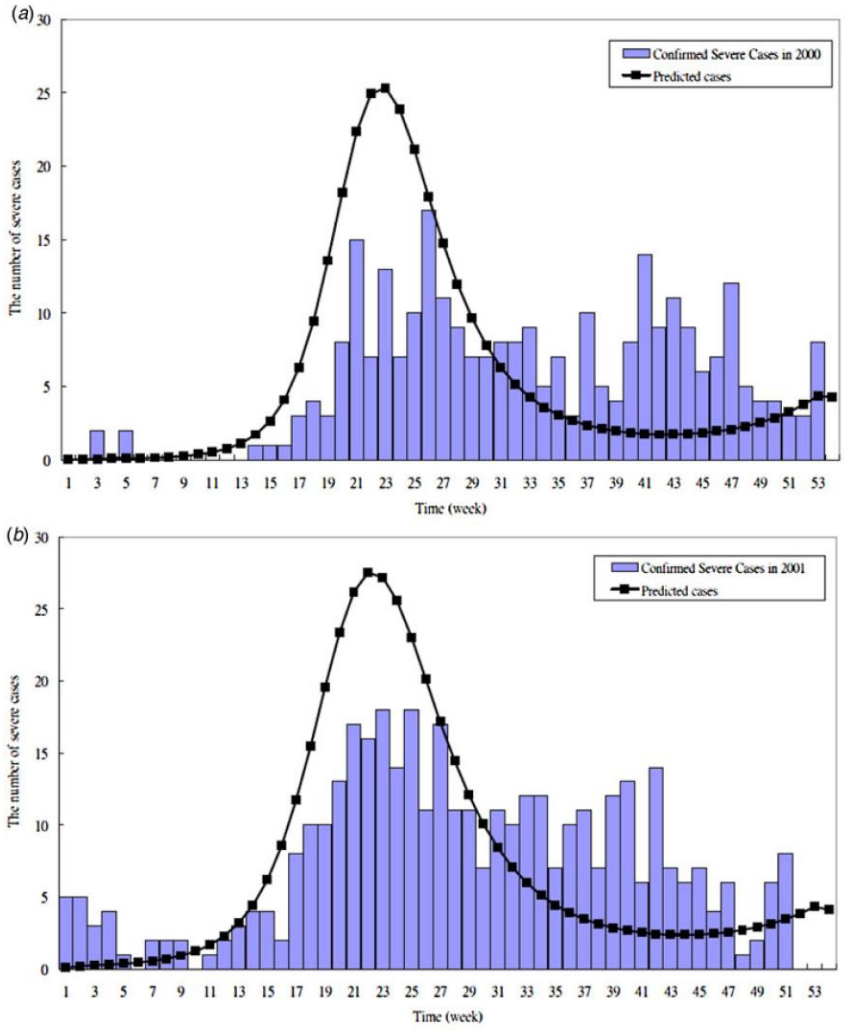


Fig. 4 (*a, b*). The observed and predicted severe HFMD cases in Taiwan in (*a*) 2000; (*b*) 2001.

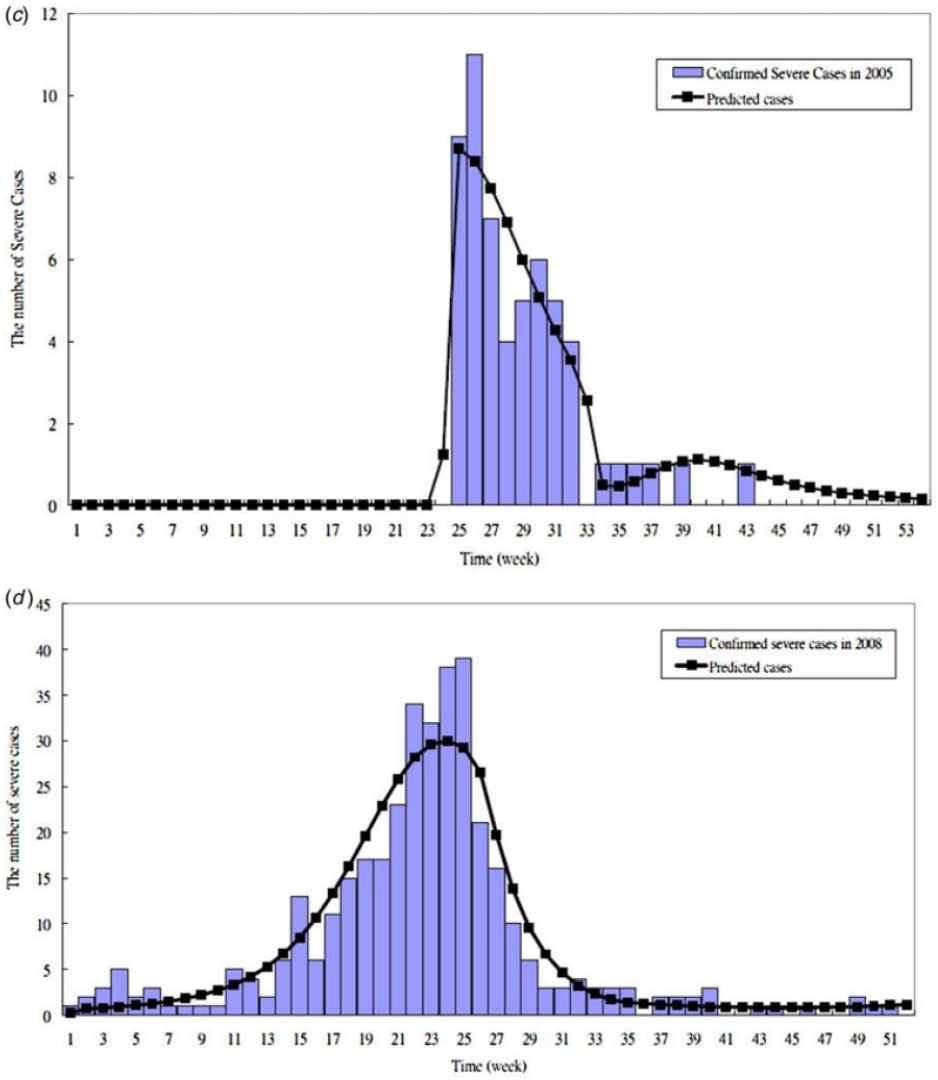
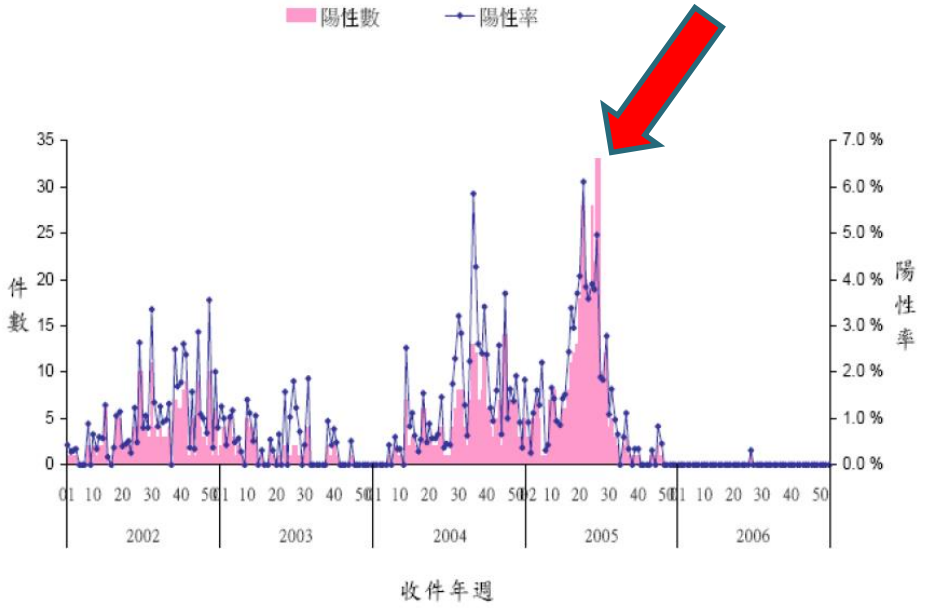
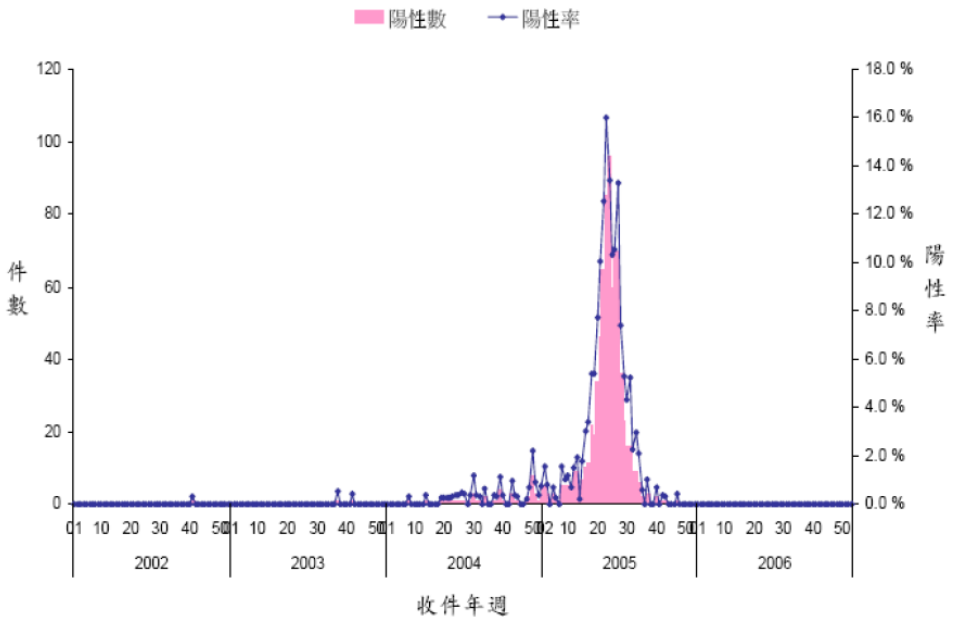


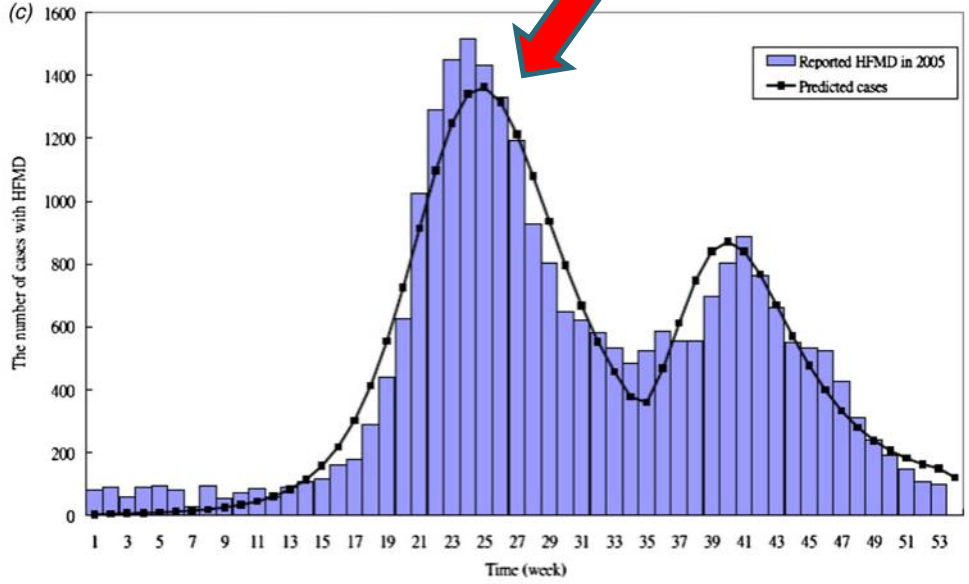
Fig. 4 (*c, d*). The observed and predicted severe HFMD cases in Taiwan in (*c*) 2005; (*d*) 2008.

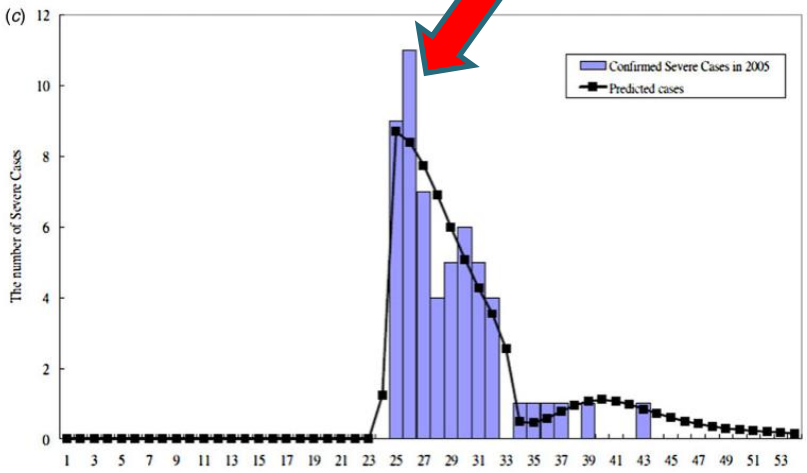
採檢定醫監測檢體 EV71 之結果



採檢定醫監測檢體 CBV3 之結果







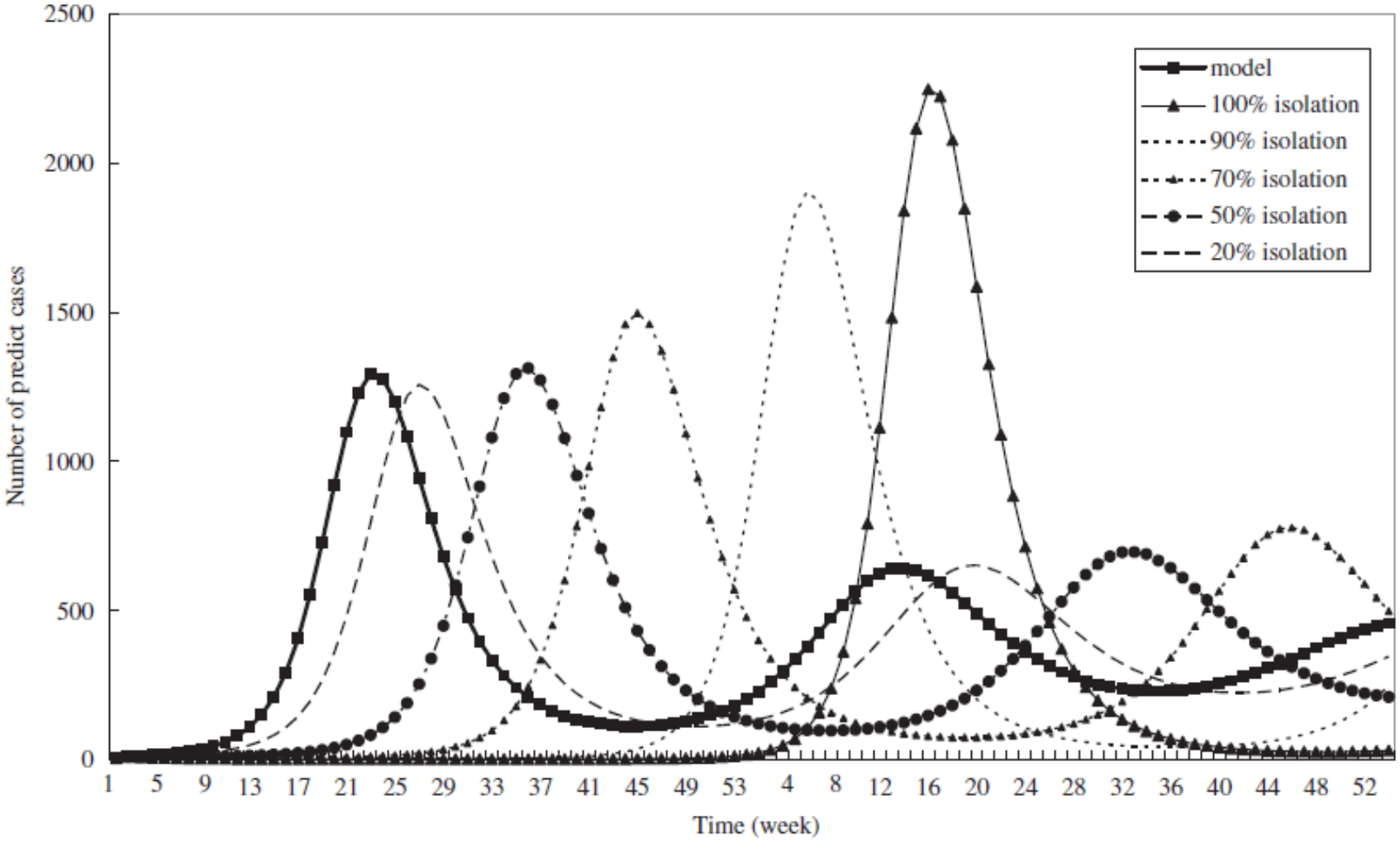


Fig. 5. The results of an isolation strategy for HFMD at different isolation rates.

- **R_0 computed was 1·37 (95% confidence interval 0·24–5·84),** suggesting a higher likelihood of the spread of HFMD

- **The isolation strategy against the spread of HFMD** not only delayed the epidemic peak with the delayed time
  - ranging from **4 weeks** for only 20% isolation to **47 weeks** 100% isolation
  - **reduced total number** of HFMD cases with the percentag reduction **ranging from 1·3% for only 20% isolation to 13·3% for 100% isolation**.

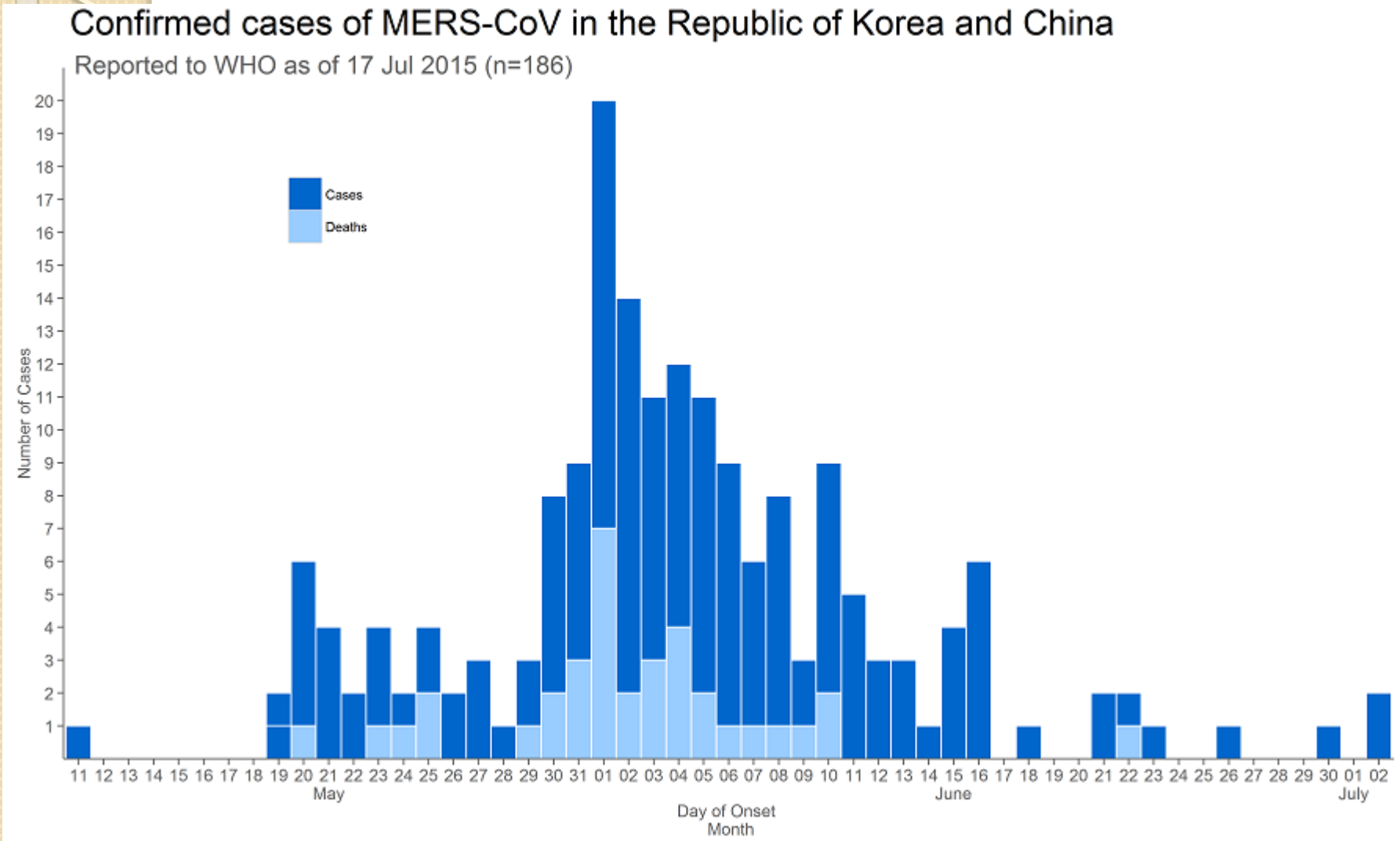
Epidemiol Infect. 2016 May;144(7):1500-11.

Stochastic Ordinary Differential Equations

- **An Example of Middle East Respiratory Syndrome**
- **Bayesian Markov Chain Monte Carlo method**

Middle East Respiratory Syndrome

TOTAL CONFIRMED	Republic of Korea	China	DEATHS
186	185	1	36



The differential equations of the three- compartmental model can be described mathematically as follows,

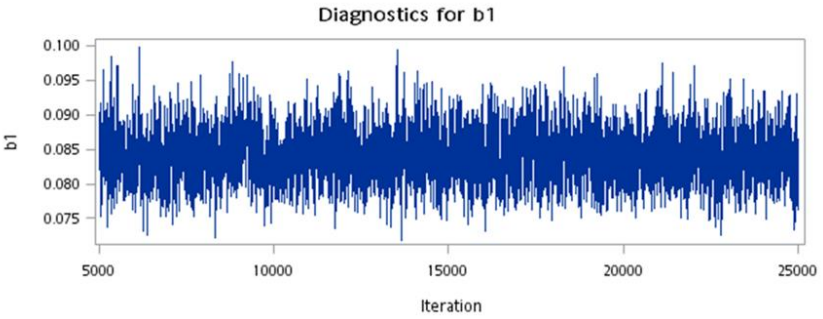
$$\frac{dS}{dt} = -\lambda S, \qquad (1)$$

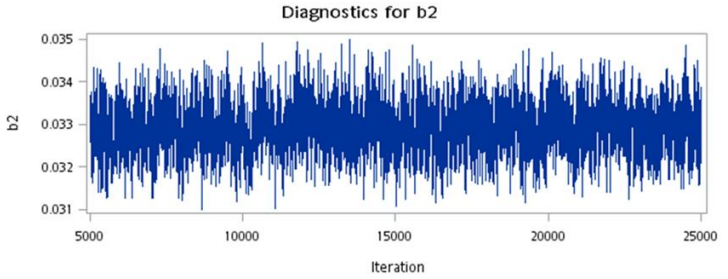
$$\frac{dI}{dt} = \lambda S - \mu I, \quad (2)$$

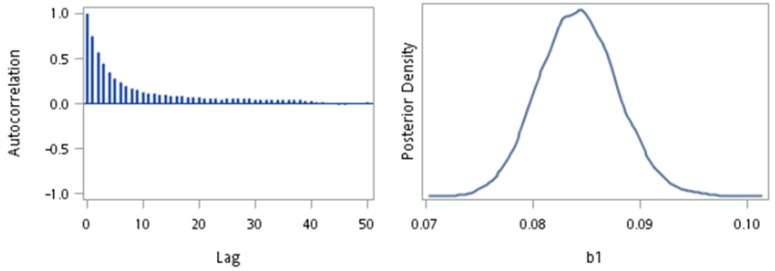
$$\frac{dR}{dt} = \mu I. \qquad (3)$$

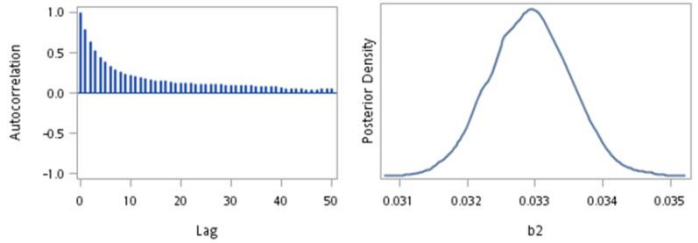
- The denote the number of susceptibles, infectious individuals.
- The distribution of S_t, I_t, and R_t at time t, with probability of $P_S(t)$, $P_I(t)$, and $P_R(t)$, respectively
- The conditional probability for the truncation of subjects of susceptible, and model number of infective as a random variable following binomial distribution

$$\text{denoted by } Bin\left([I_t + R_t], \ \frac{P_I(t)}{P_I(t) + P_R(t)} \right)$$









- R_0 was estimated 2.56 (95% Highest Posterior Density Interval 2.28 – 2.85)