## Abstract

In recent years, dengue fever (DF) is a major vector-borne disease. DF virus in humans are transmitted predominantly by the mosquito *Aedes aegypti*. The abundance and the transmission potential of *A. aegypti* are influenced by climate variables. Kaohsiung situated at south Taiwan, was a major dengue epidemic region. The purpose of this study was to characterize the risk of dengue infection based on a probabilistic transmission dynamic model and to examine the effects of climate variations on dengue patterns in Kaohsiung during 2005 – 2010. This study developed a host-vector population dynamic model to describe the disease transmission dynamics between the human and mosquito. Derived model parameters can further quantify the temperature-specific basic reproduction number ($R_0$) for deriving a $R_0$-based probabilistic risk model to estimate the risk of dengue increasing rate. This study also employed Poisson regression model based on statistic indicators to examine the potential predictors based on the monthly DF incidence rate. A hockey stick model was used to detect the potential temperature threshold. The results indicated that lagged 2 month mean ($\rho = 0.75$) and variance ($\rho = -0.73$) of temperature, mean ($\rho = 0.58$) of relative humidity, and mean ($\rho = 0.65$) and variance ($\rho = 0.63$) of rainfall were the significant predictors of dengue incidence rate in Kaohsiung. Sea surface temperature anomaly (SSTA) Niño3 with 1-month lag had better correlation with dengue incidence rate ($\rho = 0.35$). Under the mean temperature regime ($25.52 \pm 3.63^{o}$C), $R_0$ estimate was 3.47 (95% CI: 1.60 – 7.51), implicating that there had an epidemic outbreak of dengue fever in Kaohsiung. The 50% exceedance risk of dengue case increasing rate can exceed 0.35 (95%CI: 0.29 – 0.42) $wk^{-1}$ in the mean temperature scenario. This study showed that potential threshold for mean temperature with 2-month lag was 25.92 (95% CI: 24.78 – 27.07)$^{o}$C. The detected

lagged temperature threshold can be an early warning indicator to assess dengue epidemic in Kaohsiung. The host-vector model established in this study could enhance the understanding of the DF population dynamics in the tropical Taiwan. This study provided a method to determine the dominant factors in the DF trends in Kaohsiung. The research schemes could be further applied in the further to help quantify the control measure effects to contain dengue virus infection.

**Keyword:** Dengue fever; *Aedes aegypti*; El Niño-Southern Oscillation; Poisson regression model; Host-vector model; Probabilistic risk analysis

# 中文摘要

登革熱 (Dengue fever)為近年主要流行之傳染性病媒蚊疾病。而其登革熱病毒之傳染途徑最主要經由埃及斑蚊 (Aedes aegypti)傳輸至人體，且氣象條件為影響埃及斑蚊族群豐量及登革熱病毒傳輸之顯著因子。然而位於台灣南部之高雄為登革熱發生率最嚴重之地區。因此，本研究主要目的為特性化 2005 至 2010 年高雄地區登革熱感染風險，並評估氣象因子變動下之登革熱疾病趨勢。本研究建立宿主－病媒蚊 (Host – vector)模式以描述人類與蚊蟲族群之登革熱傳輸動態。推導出之模式參數可進一步量化不同溫度下之基本再生數 (Basic reproduction number, $R_0$)，藉此發展以 $R_0$ 為基礎之機率風險模式 (Probabilistic risk model)以推估登革熱增率風險。本研究亦發展以統計指標為基礎之卜瓦松迴歸模式 (Poisson regression model)評估影響登革熱每月發生率之潛在因子，最後並以曲棍球桿模式 (Hockey stick model)推估潛在溫度閾值。本研究發現遲滯 2 個月溫度之算術平均 (斯皮曼相關係數 $\rho = 0.75$)與變異數 ($\rho = -0.73$)、相對溼度之算術平均 ($\rho = 0.58$)及降雨量之算術平均 ($\rho = 0.65$)與變異數 ($\rho = 0.63$)等氣象統計指標與登革熱之相關性最為顯著。而針對聖嬰現象指標則以遲滯 1 個月 Nino3 ($\rho = 0.35$)對於登革熱之趨勢最為相關。本研究亦指出高雄於均溫情境 ($25.52 \pm 3.63^{o}C$)之 $R_0$ 為 3.47 (95%信賴區間：1.60 – 7.51)，顯示其登革熱疫情有爆發之趨勢。針對風險推估，本研究指出在 50%之超越風險 (ER = 0.5)下，均溫之登革熱增率為 0.35 (95% 信賴區間：0.29 – 0.42) $wk^{-1}$。最後本研究推估登革熱遲滯 2 個月之潛在均溫閾值為 25.92 $^{o}C$ (95% 信賴區間：24.78 – 27.07 $^{o}C$)，其結果亦可作為高雄評估登革熱疫情之預警指標。本研究建立之宿主－病媒蚊模式將有助於增進對登革熱疾病傳輸之認知，並以統計迴歸模式提供評估南台灣登革熱顯著因子之方法。因此本研

究將有利於進一步應用於未來登革熱疾病之控制策略評估成效。

**關鍵詞**：登革熱；埃及斑蚊；聖嬰－南方震盪；卜瓦松迴歸模式；宿主－病媒蚊模式；機率風險評估