Journal of Coastal Development
Volume 13, Number 3, June 2010 : 195-204

ISSN : 1410-5217
Accerdited : 83/Dikti /Kep/2009

Original Paper

HOUSEHOLD PROTECTION AGAINST DENGUE HEMORRHAGIC FEVER EPIDEMICS IN COASTAL CITY OF MAKASSAR

Halmar Halide

Physics Department, Faculty of Mathematics and Natural Sciences,
Hasanuddin University, Makassar 90245, Indonesia

Received : February,1.2010 ; Accepted : April, 5, 2010

ABSTRACT

The skill of two simple models for predicting Dengue Hemorrhagic Fever (DHF) epidemics in a coastal city of Makassar was evaluated. One model uses persistence while the other uses past dengue cases and climate factors to make predictions. It was shown that the skill of the models was not significantly different. The value of the prediction was also investigated when it was used for deciding whether or not to protect a household from epidemics. When the model predicts that a DHF epidemic was forthcoming, a highly effective but low-cost DEET product was applied to the whole family as protection against mosquito bites. It was found that the cost of implementing such model prediction was much cheaper than other options such as: (i) using protection without any forecast and, (ii) neglecting any protection. It was also found that the value of a forecast depends on forecast skill and the cost-to-loss ratio.

Keywords: DHF epidemics, predictive model, forecast value, decision making, DEET

Correspondence : +62-411-586200 ; Fax : +62-411-588551 ; e-mail : halmarh@yahoo.com

INTRODUCTION

Dengue Hemorrhagic Fever (DHF) causes a substantial burden to a family in terms of the loss of life and economic impacts (Gubler, 2002; van Damme *et al.*, 2004; Shepard *et al.*, 2004; Anderson *et al.*, 2007; Mimura *et al.*, 2007; Tseng, 2008). More importantly, those people living near the coast and low-lying areas were shown to have a high risk of getting the disease (I-Monge *et al.*, 2006; Chowell *et al.*, 2008). This could be due to factors such as: water availability which supports vector abundance (Barrera *et al.*, 2002; Ooi and Gubler, 2008; Tsuzuki *et al.*, 2009) and rapid urbanisation and population growth and international travels that promote disease dynamics and transmission (Knudsen dan Slooff, 1992; W-Smith and Schwartz, 2005; Barreto *et al.*, 2008; Hii *et al.*, 2009; Honório *et al.*, 2009; Wu *et al.*, 2009). Therefore, an early warning system (EWS), even with a 1 month lead prediction for an upcoming Dengue Hemorrhagic Fever (DHF) epidemic (Halide and Ridd, 2008), was urgently needed (Drake, 2005; Farrar *et al.*, 2007; R-Ranzinger *et al.*, 2008). Such a system can be used to make an informed decision preventing the occurrence of an epidemic at a family scale.

There were few models that could serve as a EWS. The models range in complexities and use biotic and abiotic factors to make dengue predictions. More recently a simple statistical model, HR2008, was able to give a useful epidemic prediction up to 6 months in advance (Halide and Ridd, 2008).

ISSN : 1410-5217
Accerdited : 83/Dikti /Kep/2009

In this study, the HR2008 model and a persistence model were implemented in a decision making problem as an attempt to prevent an epidemic in the coastal city of Makassar Indonesia (5.1^o S, 119.6^o E). The decision whether or not a family applies a protective measure was made based on the model's prediction. The value of a forecast was assessed through expenses resulting from several decision options.

MATERIALS AND METHODS

Data

The monthly number of confirmed DHF cases was recorded by the Public Health Division at the city of Makassar, Indonesia. Predictive models were developed using these cases. Length of stay (LOS) and cost to patients were obtained at a regional hospital RS Wahidin Sudirohusodo at Makassar during DHF epidemics, i.e. January and April. Attention was given to patients who occupied rooms with the least expensive rates. Other demographic data such as household size was obtained from Makassar Bureau of Statistics.

Model and predictions

The two models used to give a 1-month lead prediction of DHF epidemics were briefly described. An epidemic was defined when the number of DHF cases exceeds the 75th percentiles (Nisalak *et al.*, 2003). The models were:

(i) a persistence model which states that the number of DHF cases in the following month was the same as that of the present month i.e.

$N\ (t+1)=N(t)$ [1]

Where $N\ (t)$ was the number of cases at time t (measured in months)

(ii) a DHF predictive model HR2008 developed earlier (Halide and Ridd, 2008). This model uses both past DHF cases and local meteorological variables such as relative humidity h and average temperature T_{ave} to predict cases in the following month. The model was run on DHF data from January 1999 to December 2005 period and gives the following closed form formula for predicting the number of cases a month in advance:

$N(t+1)=0.73N(t)–3.44h(t\text{-}4)\text{-}16.43T_{ave}(t\text{-}5)+732.45$ [2]

Note that the HR2008 model was capable of producing a useful prediction skill up to 6 months in advance against a no-skill random forecast (Halide and Ridd, 2008).

Prediction skill assessment

In order to assess prediction skill of these two models, we use predictions covering the period from February 1999 to December 2005, i.e. 83 months. The skill of each model was determined by its Peirce score using a contingency table as shown in **Table 1** In this table a, b, c, and d refer respectively to the number of times the epidemic was not forecast but did occur, and the epidemic was neither forecast nor observed. The score and its error estimate were calculated using data from **Table 1** and the following formulas below (Stephenson, 2000).

Table 1. Contingency table for the Yes/No DHF epidemic forecast (Halide and Ridd, 2008)

DHF epidemic predicted	DHF epidemic observed	
	Yes	No
Yes	*a* (hit)	*b* (false alarm)
No	*c* (miss)	*d* (correct rejection)

 ISSN : 1410-5217
Accerdited : 83/Dikti /Kep/2009

Peirce skill score $PSS = (ad-bc) / (a+c)(b+d)$ (3)

Standard error $ePSS = [(n^2-4(a+c)(b+d)PSS^2)/4n(a+c)(b+d)]^{1/2}$ (4).

where the total number of predictions and observations $n = a+b+c+d$.

The prediction skill of a model was usually compared against a random no-skill forecast by first transforming the above *a, b, c, d* values as:

$a_r=(a+c)(a+b)/n$ (5)

$b_r=(b+d)(a+b)/n$ (6)

$c_r=(a+c)(c+d)/n$ (7)

$d_r=(b+d)(c+d)/n$ (8),

and then the transformed values (5-8) were substituted into (3) and (4) to obtain score and error for the random forecast.

Decision making problem

A household based its decision whether or not to take any protective measures depending on a model forecast. The family will only take protective measures against epidemic when a model predicts that the event was forthcoming. In this case the family member applies a highly effective but low-cost DEET product daily for a personal protection (Klun *et al.,* 2004). Note that this mode of protection was selected amongst other forms of domestic interventions such as the use of biological agents (Kay *et al.,* 2002) and larval controls (McConnell and Gubler, 2003; Paeporn *et al.,* 2003; Suaya *et al.,* 2007) because it directly protects a person both in and outside the house from mosquito bites. The economic value of using such a model forecast for taking a decision was examined below.

Forecast value evaluation

The value of a decision was examined in terms of cost C and loss L. The former occurs when the family uses a daily protection and the loss incurs when the un-protected family suffers from an epidemic. Note that one could also perform a cost-benefit analysis, i.e. a benefit was the savings resulting from taking a protection. Beside a forecast-led decision, there were also other options to consider. They were: the family applies a daily protection regardless of any forecast and the family does not use any protection at all. The expense E for each decision was calculated using Thornes and Stephenson (2001) formulation:

E1 (for not using any protection) = (a+c) × L (9)

E2 (for a daily protection regardless of any forecast) = (a+b+c+d) × C (10)

E3 (for using a predictive model) = ((a+b) × C) + (c × L) (11)

E4 (for using perfect forecast) = (a+c) × C (12).

The value of a forecast was presented as a value index and calculated using the above expenses as:

VI = (E2-E3)/(E2-E4) (13).

RESULTS AND DISCUSSIONS

Models skill

Observed DHF cases (circled) and out-of-sample predictions (lined) of cases for both predictive ‘HR2008’ and ‘Persistence’ models were presented in **Fig. 1** We also plot a horizontal dotted-line at dengue cases equals to 134 at 75% percentiles to assign epidemic events. **Fig. 1** shows that the HR2008 model correctly predicts the moderately severe epidemics peaks in 2001 to 2005. These epidemics, however, were predicted to occur one month later by the persistence model as expected. It also found that the HR2008 wrongly predicts higher cases in 1999 and 2000 and few negative cases in year 1999. None of the latter problems were found in the persistence model.

ISSN : 1410-5217
Accerdited : 83/Dikti /Kep/2009

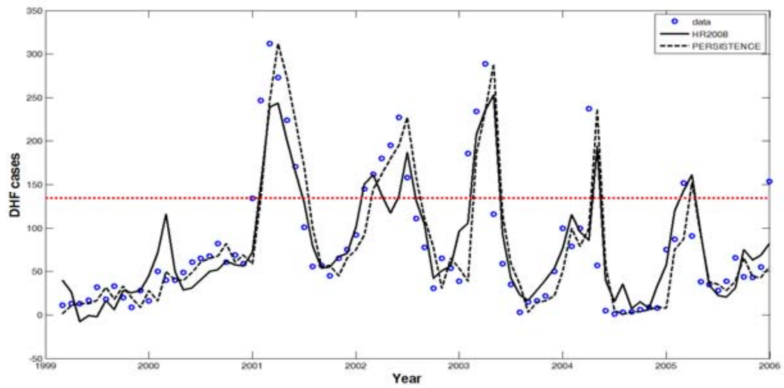


Fig. 1. Data (observed DHF cases) and the out-of-sample predictions of DHF cases at one month in advance for the HR2008 and persistence models. The horizontal dotted line represents the 75% percentiles of DHF cases.

The contingency parameters and forecast skills for both models were presented in **Table 2 and Fig. 2.** The one month delay in predicting these epidemics seems to lower the number of hit rates *a*, and the correct rejections *d* obtained by the persistence model compare to that of the HR2008 model. The Peirce skill score, however, was not significantly different from each model. Both models have a much higher skill than that of the random forecast.

Table 2. Prediction skill of the HR2008 and persistence models and their corresponding no-skill forecasts (in brackets)

Parameters	Model	
	HR2008	Persistence
a	18 (7)	16 (6)
b	5 (6)	7 (17)
c	7 (8)	6 (16)
d	53 (42)	54 (44)
Peirce skill score	0.63±0.10 (0.0±0.12)	0.61±0.10 (-0.01±0.12)

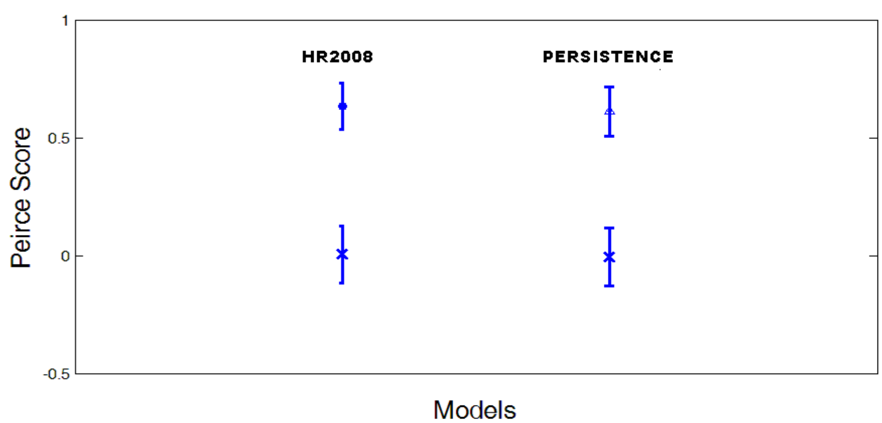


Fig. 2. Peirce skill scores including the error estimates (error bar) for both predictive models HR2008 (circle) and Persistence (upper triangle) and their associated no-skill random models in crosses (×), respectively.

 ISSN : 1410-5217
Accerdited : 83/Dikti /Kep/2009

Models' forecast value Cost of protection

The household size in Makassar ranges from 3.16 to 5.26 people and the average of 4.26 from the total population of Makassar of about 1,223,540 (Central Board of Statistics/BPS, 2006). The minimum monthly regional wage in 2006 was US$55.64 (Central Board of Statistics/BPS, 2006). Here we use a conversion rate of 1 US$ equals to 11,000 Indonesian Rupiahs during the evaluation period. Let us suppose a family of four people to be protected against an epidemic. The mode of protection uses an insect-repellent called AUTAN. This product comes in a lotion which contains 12.5 % DEET. It was packed in a sachet weighting 10g. Each person applies the product twice a day, i.e. two sachets, for 12h protection during daytime according to an efficacy test (Constantini *et al.*, 2004). One sachet of AUTAN costs 4.5 cents. The total cost for protecting a family of four people in 30 days therefore equals to US$10.9.

Loss due to DHF epidemics

If a member of the family was not protected against dengue-carrying mosquito bites, he/she has the risks of getting hospitalised due to DHF. Length of stay (in nights) of a DHF patient during the 2008 epidemics in Wahidin Sudirohusodo hospital ranges from 1 to 8 days with an average of 4.8 days. The economic loss for each night spent in the least expensive room was presented in **Table 3.** The cost includes: blood exam, treatment, meals, visit by physicians and nurses, and rooms. The cost to loss ratios C/L, expenses and the value index of the two predictive models were also presented in **Table 3 and Fig.3**.

In **Table 3**, expense resulting from implementing a forecast E3 was cheaper than those of no-protection E1 and protection without any forecast E2 options. **Table 3** also shows that both models give similar forecast value. Their corresponding no-skill random forecasts have lower forecast value due to their low skill (**Table 2**). It was also found that as the C/L ratio gets smaller, the forecast value decreases (**Fig. 3**). Note that value index VI of the no-skill forecast contains some non-positive value. In such a case, the forecast has no value, i.e. it was better just to use a daily protection regardless of any prediction.

In **Table 3**, expense resulting from implementing a forecast E3 was cheaper than those of no-protection E1 and protection without any forecast E2 options. **Table 3** also shows that both models give similar forecast value. Their corresponding no-skill random forecasts have lower forecast value due to their low skill (**Table 2**). It was also found that as the C/L ratio gets smaller, the forecast value decreases (**Fig. 3**). Note that value index VI of the no-skill forecast contains some non-positive value. In such a case, the forecast has no value, i.e. it was better just to use a daily protection regardless of any prediction.

This study was the first to implement and determine the value of a prediction by using a single mode of protection against DHF epidemics using an insect repellent. It was shown that the forecast implementation has an economic value. The value depends on factors such as forecast skills and the cost to loss ratio. Simple protection using a DEET-based repellent was rarely used as a means for community protection against epidemics.

The DEET-based product was highly effective and has a broad-spectrum protection against mosquitoes, ticks, flies and insects bite (Fradin and Day, 2002; Klun *et al.*, 2006). Depending on application dosage and DEET concentrations, the product was able to give protection up to 7 hours (Fradin and Day, 2002; Kalyasundaram and Mathew, 2006). This product was also safe for adult and children providing that the dosage was properly applied (Katz *et al.*, 2008). It was not surprising that DEET was still considered as the single most effective personal protection for many years (W-Smith and Schwartz, 2005). However, this mode of

ISSN : 1410-5217
Accerdited : 83/Dikti /Kep/2009

protection has not been widely used in a population against DHF epidemics.

Table 3. Forecast value of the HR2008 and Persistence models. Expenses and value index for their corresponding no-skill forecasts in brackets. The cost C for protecting a family of four people was US$ 10.9. E2 and E4 were the same for all nights. Note that the figures in squared-brackets were the number of patients with corresponding LOS.

Model	Parameters	Length of stay in hospital LOS (nights)							
		1 [3]	2 [13]	3 [8]	4 [9]	5 [3]	6 [0]	7 [2]	8 [1]
	Loss (L) (US$)	15.0	23.2	31.4	39.5	47.7	55.9	64.1	72.3
	C/L	0.73	0.47	0.35	0.28	0.23	0.20	0.17	0.15
HR2008	E1 (US$)	375.0 (375.0)	579.5 (579.5)	784.1 (784.1)	988.6 (988.6)	1,193.2 (1,193.2)	1,397.7 (1,397.7)	1,602.3 (1,602.3)	1,806.8 (1,806.8)
	E2 (US$)	905.5 (905.5)							
	E3 (US$)	355.9 (520.9)	413.2 (668.2)	470.4 815.4)	527.7 962.7)	585.0 (1,110.0)	642.3 (1,257.3)	699.5 (1,404.5)	756.8 (1,551.8)
	E4 (US$)	272.7 (272.7)							
	VI	0.87 (0.61)	0.78 (0.38)	0.69 (0.14)	0.60 (-0.09)	0.51 (-0.32)	0.42 (-0.56)	0.32 (-0.79)	0.23 (-1.02)
Persistence	E1 (US$)	330.0 (330.0)	510.0 (510.0)	690.0 (690.0)	870.0 (870.0)	1050.0 (1050.0)	1,230.0 (1,230.0)	1,410.0 (1,410.0)	1,590.0 (1,590.0)
	E2 (US$)	905.5 (905.5)							
	E3 (US$)	340.9 (490.9)	390.0 (621.8)	439.1 (752.7)	488.2 (883.6)	537.3 (1,014.5)	586.4 (1,145.5)	635.5 (1,276.4)	684.5 (1,407.3)
	E4 (US$)	240.0 (240.0)							
	VI	0.85 (0.62)	0.77 (0.43)	0.70 (0.23)	0.63 (0.03)	0.55 (-0.16)	0.48 (-0.36)	0.41 (-0.56)	0.33 (-0.75)

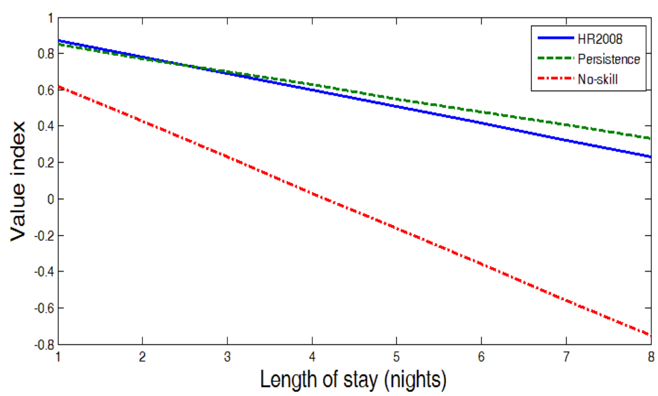


Fig. 3. Calculated forecast values of predictive models including the no-skill random forecasts for a DHF patient at the hospital.

There were at least two reasons why the population at large still reluctant to use a DEET product against epidemics. First, it might affect human skin since the product was known to be corrosive to fabrics, plastic and vinyl (Brown and Hebert 1997). Secondly, skin irritation, poisoning and toxicity occurrence have been reported in cases of excessive dosage (Vijayaraghavan *et al.*, 1991; A-Donia *et al.*, 2004). Therefore it

ISSN : 1410-5217
Accerdited : 83/Dikti /Kep/2009

was important to make sure that the product was used properly. The following recommendations to be followed were: there should be a 6 hour interval between DEET applications and the repellent should not be orally-ingested (Schaefer and Peters, 1992; Hexel *et al.,* 2008). In addition, for infants above 2 months old, the product was limited to one application per-day and the maximum DEET concentration was 30% (Koren *et al.,* 2003; Hexel *et al.,* 2008).

CONCLUSIONS

The skill of two simple models for predicting DHF epidemics in a coastal city of Makassar was assessed using a Peirce score. The skill of HR2008 model was not significantly different than that of a persistence model. Both models have a much higher skill than those of their corresponding no-skill random forecast. Both model predictions were also applied to determine whether or not a family should take protective measures against mosquito bites. In order to avoid mosquito bites, use of a DEET based repellent was proposed and simulated. It was found that the cost of implementing DEET application based upon model predictions was lower than that of other options such as: never using any protection and never using any forecast when applying a protection. It was also shown that both models have similar forecast value and they have much higher economic value than that of no-skill forecast. The forecast value gets smaller as the C/L ratio decreases.

ACKNOWLEDGEMENTS

We thank Mr Suherman, a medical staff at Wahidin Sudirohusodo public hospital in Makassar, who provides us with the expenses and LOS data of DHF patients from the hospital. He presently enrols in a Medical Physics program at Physics Department Hasanudun University. Comments by two anonymous reviewers were greatly appreciated.

REFERENCES

A-Donia, M., A.M. Dechkovskaia, L.B. Goldstein, A. A-Rahman, S.L. Bullman, and W.A. Khan. 2004. Co-exposure to pyridostigmine bromide, DEET, and/or permethrin causes sensorimotor deficit and alterations in brain acetylcholinesterase activity. *Pharmacol. Biochem. Behav.* 77: 253–262.

Anderson, K.B., S. Chunsuttiwat, A. Nisalak, M.P. Mammen, D.H. Libraty, A.L. Rothman, S. Green, D.W. Vaughn DW, F.A. Ennis, and T.P. Endy. 2007. Burden of symptomatic dengue infection in children at primary school in Thailand: a prospective study. *Lancet* 369: 1452-1459.

Barrera, R., N. Delgado, M. Jiménez, and S. Valero. 2002. Eco-epidemiological Factors Associated with Hyperendemic Dengue Haemorrhagic Fever in Maracay City, Venezuela. *Dengue Bull.* 26: 109-120.

Barreto, F.R., M.G. Teixeira, M.C.N. Costa, M.S. Carvalho, and M.L. Barreto. 2008. Spread pattern of the first dengue epidemic in the city of Salvador, Brazil. *BMC Public Health* 8: 51.

Brown, M., and A.A. Hebert. 1997. Insect repellents: An overview. *J. Am. Acad. Dermatol.* 36: 243-249.

Central Board of Statistics (BPS). Makassar in Figures, 2006 and South Sulawesi in Figures, 2006.

Chowell, G., C.A. Torre, C. M-Escate, L. S-Ognio, R. L-Cruz, J.M. Hyman and C. C-Chavez. 2008. Spatial and temporal dynamics of dengue fever in Peru: 1994–2006. *Epidemiol. Infect.* 136:1667-1677.

Constantini, C., A. Badolo, E., and I-Sanogo. 2004. Field evaluation and the efficacy and persistence of insect repellents DEET, IR3535, and KBR3023 against Anopheles gambiae complex and other Afrotropical vector mosquitoes. *Trans. R. Soc. Trop. Med. Hyg.* 98: 644-652.

van Damme, W., L. van Leemput, I. Por, W. Hardeman, and B. Meessen. 2004. Out-of-pocket health expenditure and debt in poor households: evidence from Cambodia. *Trop. Med. Int. Health* 9: 273–280.

Drake, J.M. 2005. Fundamental limits to the precision of early warning systems for epidemics of infectious diseases. *PLoS Medicine* 2, e144.

Farrar, J., D. Focks, D. Gubler, R. Barrera, M.G. Guzman, C. Simmons, S. Kalayanarooj, L. Lum, P.J. McCall, L. Lloyd, O. Horstick, R. D-Drager, M.B. Nathan, and A. Kroeger. 2007. Towards a global dengue research agenda. *Trop. Med. Int. Health* 12: 695-699.

Fradin, M.S., and J.F. Day. 2002. Comparative efficacy of insect repellents against mosquito bites. *N. Engl. J. Med.* 347: 13-18.

Gubler, D.J. Epidemic dengue/dengue hemorrhagic fever as a public health, social and economic problem in the 21st century. 2002. *Trends Microbiol.* 10:100-103.

Halide, H., and P. Ridd. 2008. A predictive model for Dengue Haemorrhagic Fever (DHF) epidemics. *Int. J. Environ. Health Res.* 18: 253-265.

Hexsel, C.L., S.D. Bangert, A.A. Hebert, and H.W. Lim. 2008. Current sunscreen issues: 2007 Food and Drug Administration sunscreen labelling recommendations and combination sunscreen/insect repellent products. *J. Am. Acad. Dermatol.* 59: 316-323.

Hii, Y.L., J. Rocklöv, N. Ng, C.S. Tang, F.Y. Pang and R. Sauerborn. 2009. Climate variability and increase in intensity and magnitude of dengue incidence in Singapore. *Glob. Health Action* 2: 10.3402/gha.v2i0.2036. .

Honório, N.A., R.M.R. Nogueira, C.T. Codeço, M.S. Carvalho, O.G. Cruz, M.A.F.M. Magalhães, J.M.G. de Araújo, E.S.M. de Araújo, M.Q. Gomes, L.S. Pinheiro, C.S. Pinel, and R.L. de-Oliveira. 2009. Spatial Evaluation and Modeling of Dengue Seroprevalence and Vector Density in Rio de Janeiro, Brazil. *PLoS Negl Trop Dis.* 3: e545.

I-Monge, R., M.L. A-Agüero, C.R. A-Agüero, T. M-Moya, A. C-Coto, K. C-Badilla, and B. Z-Mora. 2006. Seroprevalence of dengue virus antibodies in asymptomatic Costa Rican children, 2002-2003: a pilot study. *Rev. Panam. Salud. Publ.* 20: 39-43.

Kalyanasundaram, M., and N. Mathew. 2006. *N,N*-diethyl phenylacetamide (DEPA): a safe and effective repellent for personal protection against hematophagous arthropods. *J. Med. Entomol.* 43: 518-525.

Katz, T.M., J.H. Miller, and A.A. Hebert. 2008. Insect repellents: Historical perspectives and new developments. *J. Am. Acad. Dermatol.* 58: 865-871.

Kay, B.H., V.S. Nam, T.V. Tien, N.T. Yen, T.V. Phong, V.T.B. Diep, T.U. Ninh,

ISSN : 1410-5217
Accerdited : 83/Dikti /Kep/2009

A. Bektas, and J.G. Aaskov. 2002. Control of *Aedes* vectors of dengue in three provinces of Vietnam by use of *Mesocyclops* (Copepoda) and community-based methods validated by entomologic, clinical, and serological surveillance. *Am. J. Trop. Med. Hyg.* 66: 40–48.

Klun, J.A., A. Khrimian, and M. Debboun. 2006. Repellent and deterrent effects of SS220, Picaridin and DEET suppress human blood feeding by *Aedes aegypti*, *Anopheles stephensi*, and *Phlebotomus papatasi*. *J. Med. Entomol.* 43: 34-39.

Klun, J.A., D. Strickman, E. Rowton, J. Williams, M. Kramer, D. Roberts, and M. Debboun. 2004. Comparative resistance of *Anopheles albimanus* and *Aedes aegypti* to *N,N*-Diethyl-3-methylbenzamide (Deet) and 2-Methylpiperidinyl-3-cyclohexen-1-carboxamide (AI3-37220) in laboratory human-volunteer repellent assays. *J. Med. Entomol.* 41: 418-422.

Knudsen, A.B. and R. Slooff. 1992. Vector-borne disease problems in rapid urbanization: new approaches to vector control. *Bull World Health Organ*. 70: 1-6.

Koren, G., D. Matsui, and B. Bailey. 2003. DEET-based insect repellents. Safety implications for children, pregnant and lactating women. *Can. Med. Assoc. J.* 169: 209.

McConnell, K.J., and D.J. Gubler. 2003. Guidelines on the cost-effectiveness of larval control programs to reduce dengue transmission in Puerto Rico. *Rev. Panam. Salud. Publ.* 14: 9-16.

Mimura, N., L. Nurse, R.F. McLean, J. Agard, L. Briguglio, P. Lefale, R. Payet, and G. Sem. 2007. Small islands. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. (Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE, eds.), Cambridge University Press, Cambridge, UK, P. 687-716.

Nisalak, A., T.P. Endy, S. Nimmannitya, S. Kalayanarooj, U. Thisayakorn, R.M. Scott, D.S. Burke, C.H. Hoke, B.L. Innis, and D.W. Vaughn. 2003. Serotype-specific dengue virus circulation and dengue in Bangkok, Thailand from 1973-1999. *Am. J. Trop. Med. Hyg.* 68: 191-202.

Ooi, E-E., and D.J. Gubler. 2008. Dengue in Southeast Asia: epidemiological characteristics and strategic challenges in disease prevention. *Cad. Saúde Pública* 25 Sup 1:S115-S124.

Paeporn, P., N. Komalamisra, V. Deesin, Y. Rongsriyam, Y. Eshita, and S. Thongrungkiat. 2003. Temephos resistance in two forms of *Aedes Aegypti* and its significance for the resistance mechanism. *SE Asian J. Trop. Med.* 34: 786-792.

Runge-Ranzinger, S., O. Horstick, M. Marx, and A. Kroeger. 2008. What does dengue disease surveillance contribute to predicting and detecting outbreaks and describing trends? *Trop. Med. Int. Health* 13: 1022-1041.

Schaefer, C., and P.W.J. Peters. 1992. Intrauterine Diethyltoluamide exposure and fetal outcome. *Reprod. Toxicol.* 6: 175-176.

Shepard, D.S., J.A. Suaya, S.B. Halstead, M.B. Nathan, D.J. Gubler, R.T. Mahoney, D.N.C. Wang, and M.I. Meltzer. 2004. Cost-effectiveness of a

ISSN : 1410-5217
Accerdited : 83/Dikti /Kep/2009

pediatric dengue vaccine. *Vaccine* 22: 1275-1280.

Stephenson, D.B. 2000. Use of the "Odds ratio" for diagnosing forecast skill. *Weather Forecast.* 15: 221-232.

Suaya, J.A., D.S. Shepard, M-S. Chang, M. Caram, S. Hoyer, D. Socheat, N. Chantha, and M.B. Nathan. 2007. Cost-effectiveness of annual targeted larviciding campaigns in Cambodia against the dengue vector Aedes aegypti. *Trop. Med. Int. Health* 12: 1026-1036.

Thornes, J.E., and D.B. Stephenson. 2001. How to judge the quality and value of weather forecast products. *Meteorol. Appl.* 8: 307–314.

Tseng, W-C. 2008. Estimating the economic impacts of climate change on infectious diseases: a case study on dengue fever in Taiwan. *Climatic Change* 92: 123-140.

Tsuzuki, A., V.T. Duoc, Y. Higa, N.T. Yen, and M. Takagi. 2009. Effect of Peridomestic Environments on Repeated Infestation by Preadult *Aedes aegypti* in Urban Premises in Nha Trang City, Vietnam. *Am. J. Trop. Med. Hyg*. 81: 645-650.

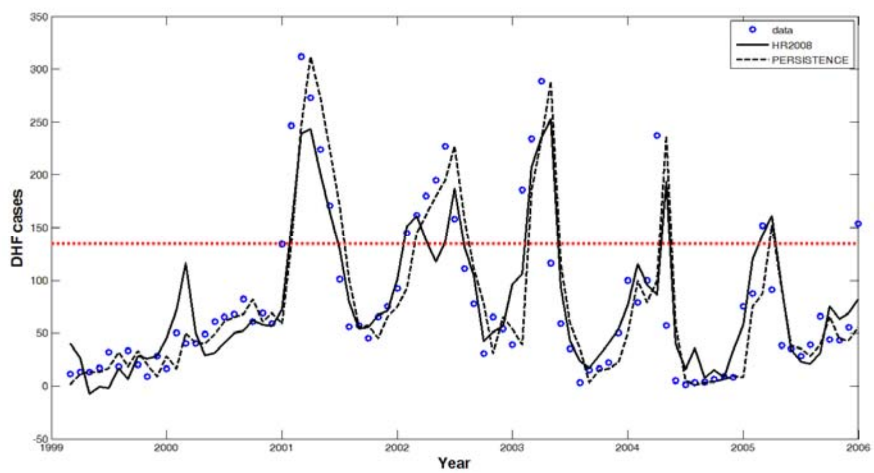
Vijayaraghavan, R., S.S. Rao, M.V.S. Suryanarayana, and R.V. Swamy. 1991. Acute and subacute inhalation toxicity studies of a new broad spectrum insect repellent, N, N-diethylphenylacetamide. *Toxicol.* 67: 85-96.

W-Smith, A., and E. Schwartz. 2005. Dengue in travellers. *N. Engl. J. Med* 353: 924-932.

Wu, P., P-C. Wu, J-G. Lay, H-R. Guo, C-Y. Lin, S-C. Lung, and H-J. Su. 2009. Higher temperature and urbanization affect the spatial patterns of dengue fever transmission in subtropical Taiwan. *Sci. Tot. Environ.* 407: 2224-2233.

ISSN : 1410-5217
Accerdited : 83/Dikti /Kep/2009

LIST OF FIGURES



Journal of Coastal Development
Volume 13, Number 3, June 2010 : 195-204

ISSN : 1410-5217
Accerdited : 83/Dikti /Kep/2009

Fig. 1. Data (observed DHF cases) and the out-of-sample predictions of DHF cases at one month in advance for the HR2008 and persistence models. The horizontal dotted line represents the 75% percentiles of DHF cases.

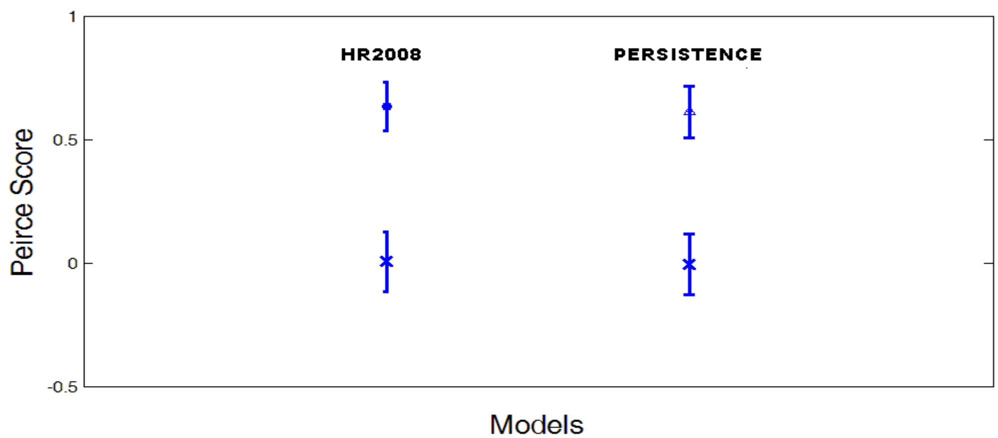


Fig. 2. Peirce skill scores including the error estimates (error bar) for both predictive models HR2008 (circle) and Persistence (upper triangle) and their associated no-skill random models in crosses (×), respectively.

ISSN : 1410-5217
Accredited : 83/Dikti /Kep/2009

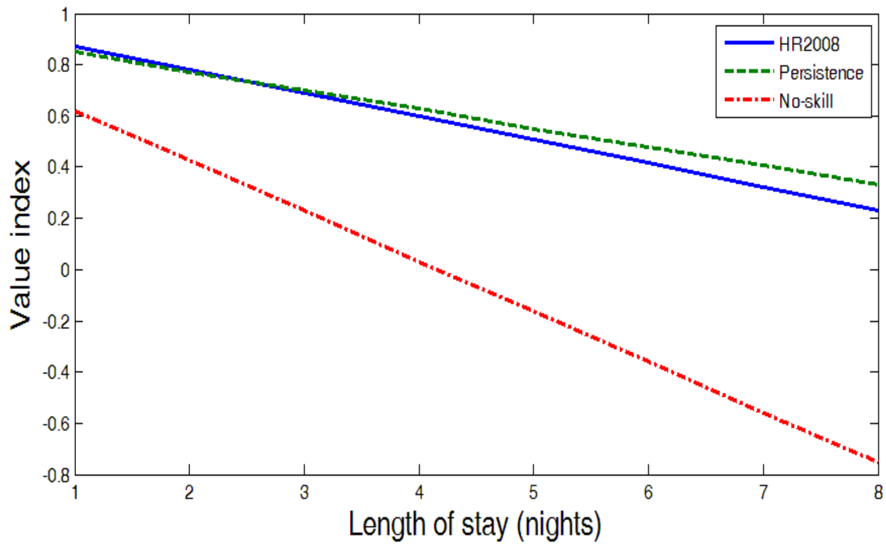


Fig. 3. Calculated forecast values of predictive models including the no-skill random forecasts for a DHF patient at the hospital.

List of Tables

Table 1. Contingency table for the Yes/No DHF epidemic forecast (Halide and Ridd, 2008)

DHF epidemic predicted	DHF epidemic observed	
	Yes	No
Yes	*a* (hit)	*b* (false alarm)
No	*c* (miss)	*d* (correct rejection)

Table 2. Prediction skill of the HR2008 and Persistence models and their corresponding no-skill forecasts (in brackets)

ISSN : 1410-5217
Accerdited : 83/Dikti /Kep/2009

Parameters	Model	
	HR2008	Persistence
a	18 (7)	16 (6)
b	5 (6)	7 (17)
c	7 (8)	6 (16)
d	53 (42)	54 (44)
Peirce skill score	0.63±0.10 (0.0±0.12)	0.61±0.10 (-0.01±0.12)

Table 3. Forecast value of the HR2008 and Persistence models. Expenses and value index for their corresponding no-skill forecasts in brackets. The cost C for protecting a family of four people was US$ 10.9. E2 and E4 were the same for all nights. Note that the figures in squared-brackets were the number of patients with corresponding LOS.

Model	Parameters	Length of stay in hospital LOS (nights)							
		1 [3]	2 [13]	3 [8]	4 [9]	5 [3]	6 [0]	7 [2]	8 [1]
	Loss (L)	15.0	23.2	31.4	39.5	47.7	55.9	64.1	72.3

	(US$)								
	C/L	0.73	0.47	0.35	0.28	0.23	0.20	0.17	0.15
HR2008	E1 (US$)	375.0 (375.0)	579.5 (579.5)	784.1 (784.1)	988.6 (988.6)	1,193.2 (1,193.2)	1,397.7 (1,397.7)	1,602.3 (1,602.3)	1,806.8 (1,806.8)
	E2 (US$)	905.5 (905.5)							
	E3 (US$)	355.9 (520.9)	413.2 (668.2)	470.4 815.4)	527.7 962.7)	585.0 (1,110.0)	642.3 (1,257.3)	699.5 (1,404.5)	756.8 (1,551.8)
	E4 (US$)	272.7 (272.7)							
	VI	0.87 (0.61)	0.78 (0.38)	0.69 (0.14)	0.60 (-0.09)	0.51 (-0.32)	0.42 (-0.56)	0.32 (-0.79)	0.23 (-1.02)
Persistence	E1 (US$)	330.0 (330.0)	510.0 (510.0)	690.0 (690.0)	870.0 (870.0)	1050.0 (1050.0)	1,230.0 (1,230.0)	1,410.0 (1,410.0)	1,590.0 (1,590.0)
	E2 (US$)	905.5 (905.5)							
	E3 (US$)	340.9 (490.9)	390.0 (621.8)	439.1 (752.7)	488.2 (883.6)	537.3 (1,014.5)	586.4 (1,145.5)	635.5 (1,276.4)	684.5 (1,407.3)
	E4 (US$)	240.0 (240.0)							
	VI	0.85 (0.62)	0.77 (0.43)	0.70 (0.23)	0.63 (0.03)	0.55 (-0.16)	0.48 (-0.36)	0.41 (-0.56)	0.33 (-0.75)