THESIS

ACTIVITY AND BIONOMIC ASPECTS OF PRIMARY AND SECONDARY VECTORS FOR DENGUE TRANSMISSION IN GAMPAHA DISTRICT, SRI LANKA

Submitted by

C.P.R.D.DALPADDO

(FGS/ 01/PhD/07/2016/50)

A thesis submitted to the Faculty of Graduate Studies, University of Kelaniya

in fulfillment of the requirements for the degree of

Doctor of Philosophy in Medical Entomology

February 2022

This thesis has been accepted by the University of Kelaniya for the award of the Degree of Doctor of Philosophy (2022) It is not allowed to Publish this as a thesis accepted for the Degree of Doctor of Philosophy without the authority of the University

Deputy Registrar / Examinations

THESIS

ACTIVITY AND BIONOMIC ASPECTS OF PRIMARY AND SECONDARY VECTORS FOR DENGUE TRANSMISSION IN GAMPAHA DISTRICT, SRI LANKA

Submitted by

C.P.R.D.DALPADDO

(FGS/ 01/PhD/07/2016/50)

A thesis submitted to the Faculty of Graduate Studies, University of Kelaniya

in fulfillment of the requirements for the degree of

Doctor of Philosophy in Medical Entomology

February 2022

To my family members and teachers

DECLARATION

I declare that the work embodied in the thesis is my own and has not been submitted for any degree in this university or any other institute, and to the best of my knowledge and belief, it does not contain any material previously published or written or orally communicated by another person except, where due reference is made in the text.

.... Signature of the candidate

12/09/2022
.... Date

To the best of our knowledge, we endorse the declaration by the candidate.

Main supervisor

.... Prof. Mrs L.D. Amarasinghe, Professor, Department of Zoology and Environmental Management, Faculty of Science, University of Kelaniya, Sri Lanka.

Co-supervisors

.................................Prof. P.A.D.H.N. Gunanthilaka, Professor, Department of Parasitology, Faculty of Medicine, University of Kelaniya, Sri Lanka.

I. CONTENTS

II. LIST OF FIGURES

III. LIST OF TABLES

IV. LIST OF APPENDICES

V. LIST OF ABBREVIATIONS

Ae.	*Aedes*
A/C	Air Conditioner
ARIMA	Auto Regressive Integrated Moving Average
BI	Breteau Index
$BIA_{(t-1)}$	Breteau Index for *Ae. aegypti* at one month lag
$BIB_{(t-1)}$	Breteau Index for *Ae. albopictus* at one month lag
$BIAR_{(t-1)}$	Breteau Index for *Ae. aegypti* in rural areas at one month lag
$BIAS_{(t-1)}$	Breteau Index for *Ae. aegypti* in suburban areas at one month lag
$BIAU_{(t-1)}$	Breteau Index for *Ae. aegypti* in urban areas at one month lag
$BIBR_{(t-1)}$	Breteau Index for *Ae. albopictus* in rural areas at one month lag
$BIBS_{(t-1)}$	Breteau Index for *Ae. albopictus* in suburban areas at one month lag
$BIBU_{(t-1)}$	Breteau Index for *Ae. albopictus* in urban areas at one month lag
$BIMR_{(t-1)}$	Cumulative Breteau Index in rural areas at one month lag
$BIMS_{(t-1)}$	Cumulative Breteau Index in suburban areas at one month lag
$BIMU_{(t-1)}$	Cumulative Breteau Index in urban areas at one month lag
Bti	*Bacillus thuringiensis*
^0C	Celsius
CCF	Cross-Correlation Function
CI	Container Index
CDC	Centre for disease control and prevention
DDT	Dichlorodiphenyltrichloroethane
CFR	Case Fatality Rate

ChE	Cholinesterase
cm	centimeter
DENV	Dengue Virus
df	degree of freedom
DF	Dengue Fever
DHF	Dengue Hemorrhagic Fever
DI	Disease Incidence
DIR	Disease Incidence; Rural
DIS	Disease Incidence; Suburban
DIU	Disease Incidence; Urban
DO	Dissolved Oxygen
DS	Divisional Secretariats
DSS	Dengue Shock Syndrome
EC	Emulsifiable concentrate
ECDC	European Centre for Disease Prevention and Control
EIP	Extrinsic incubation period
F0	Zeroth generation/ wild generation
F1	First generation
FAO	Food and Agriculture Organization
GR	Granules
GN	Grama Niladhari
HI	House Index
IIP	Intrinsic incubation period
IVM	Integrated Vector Management
l	liter

LC	Lethal concentrations
L:D	Light: Dark
Lg DI	Log-transformed disease incidence
m	meter
mg	miligrams
ml	milliliter
mm	millimeter
MOH	Medical Officer of Health
MLR	Multiple Linear Regression
NDCU	National Dengue Control Unit
NTU	Nephelometric Turbidity unit
Ops	Organophosphates
PHI	Public Health Inspector
ppm	parts per million
$RD_{(t-2)}$	Rainy days at two-month lag
$RFavg_{(t-2)}$	Average monthly rainfall at lag two months
$RFmax_{(t-2)}$	Monthly maximum rainfall at lag two months
$RFtot_{(t-2)}$	Total monthly rainfall at lag two months
$RHavg_{(t-2)}$	Monthly average relative humidity a two-month lag
RH	Relative Humidity
RNA	Rhibo Nucleic Acid
SD	Standard Deviation
SG	Sand granules
SPSS	Statistical Package for the Social Sciences
$Tavg_{(t-3)}$	Monthly average atmospheric temperature at three-month lag

TDS	Total dissolved solids
TSS	Total suspended solids
ULV	Ultra-Low Volume
WDP	water-dispersible powders
WP	Wettable powders
WQI	Water Quality Index
WHO	World Health Organization
µs	microsiemens

VI. ACKNOWLEDGEMENTS

My deepest gratitude and sincere appreciation is extended to my main supervisor Prof. (Mrs) L. D. Amarasinghe, Professor, Department of Zoology and Environmental Management, University of Kelaniya, for her guidance, encouragement, and many useful suggestions during my Ph.D. research activities and writing of the dissertation. I appreciate all her contributions of time, ideas, and funding to make my Ph.D. productive and stimulating.

I am extremely grateful to Prof. P. A. D. H. Nayana Gunathilaka, Professor, Department of Parasitology, Faculty of Medicine, University of Kelaniya who is my co-supervisor, for his guidance, encouragement, and many useful suggestions during my Ph.D. research activities and writing of the dissertation. I also thank Prof. P. A. D. H. Nayana Gunathilaka for his technical co-operation for the laboratory studies.

My sincere thanks also go to Prof. (Mrs.) Annista Wijayanayake, Professor, Department of Industrial Management, University of Kelaniya for her guidance for the statistical analysis and modelling part of the current study.

I gratefully acknowledge Dr. A. L. Fareed, The Provincial Director of Health Service, Western province and Dr. Nalin Ariyarathna, The Regional Director of Health Service, Gampaha district, who has permitted me to utilize the district entomological teams, laboratory and research facilities for conducting the study and allowing me to plan all the district entomological activities base on the requirements of the current research study. I would also like to thank all the Health Entomological Officers and other staff members of the Gampaha district entomology team for their kind cooperation and generous help is given throughout the study period. Further, I would like to acknowledge the National Dengue Control Unit of Sri Lanka for providing standard WHO susceptibility test kits and technical cooperation for laboratory studies.

I would also like to thank Dr Tharaka Ranathunge, Former Lecturer, Molecular Medicine Unit, Faculty of Medicine, University of Kelaniya and Dr. Lahiru Udyanga, Lecturer Department of Biosystems Engineering, Faculty of Agriculture & Plantation Management, Wayamba University of Sri Lanka for their technical guidance and many useful suggestions during my Ph.D. research activities.

My gratitude goes to Dr. Subashini Aryaprema, Senior Entomologist, Colombo district and Mrs. Sakunthala Janaki, Entomologist, National Dengue Control Unit and all other regional entomologists for their technical guidance and generous help extended throughout the study.

I would like to thank to all my colleagues for their kind cooperation. I acknowledge the co-operation and generous help given by staff members of the Department of Zoology and Environmental Management, University of Kelaniya, and Department of Parasitology, Faculty of Medicine, University of Kelaniya for their generous help throughout the study.

I gratefully acknowledge Prof. G.A.S.M Ganehiarachchi, Head of the Department and Professor, Department of Zoology and Environmental Management, University of Kelaniya for his guidance, encouragement throughout the study. I would also like to acknowledge to Prof. Sudath R D Kalingamudali, Dean, Faculty of Science, University of

Kelaniya, Dean, Faculty of the Graduate Studies University of Kelaniya and Vice-Chancellor, University of Kelaniya, for accepting my candidature for the Degree of Doctor of Philosophy.

Finally, I would also like to show my gratitude to my parents and husband, for their encouragement and support extended throughout the study.

VII. ABSTRACT

Sri Lanka had experienced periodic dengue epidemics every two to three years for the last two decades. In this scenario, understanding bionomics aspects, and the prevalence of dengue vector species in varied settings will help to develop more accurate and focused vector control approaches. Thus, the current study is intended to elucidate the bionomics of *Aedes aegypti* and *Ae. albopictus*, in urban (Negombo, Wattala, Kelaniya), suburban (Attanagalla, Gampaha, Minuwangoda) and rural (Dompe, Meerigama, Divulapitiya) areas of the Gampaha District, Sri Lanka from April 2017 to December 2019. The effectiveness of the insecticide space spraying depends on susceptibility status and the behaviour of the targeted species, hence a part of this study included testing susceptible levels of *Ae. aegypti* and *Ae. albopictus* against malathion and deltamethrin insecticides. The study also sought to establish area-specific threshold values for determining the risk of dengue transmission based on larval indices, and a forecasting model for predicting impending dengue outbreaks within the district.

Total 19,835 possible breeding habitats were investigated at 13,563 premises where *Aedes* larvae were identified in 11.03% of premises and 1856 habitats were positive for larvae (*Ae. aegypti*; 9.8%; *Ae. albopictus*; 90.2 %). Results showed that *Ae. aegypti* prefers urban locations while *Ae. albopictus* is the predominant vector in all spatial settings. *Ae. albopictus* (54.5%; n= 999) dominated the adult collection, followed by *Ae. aegypti* (45.5%; n= 835), with a 1:4 male to female ratio. *Ae. aegypti* mosquitoes demonstrated endophilic resting behaviour, whereas *Ae. albopictus* were exophilic (Chi-square analysis between the two species; $P < 0.001$). Resting places of *Aedes aegypti* recorded as on cloth hangings (36.9%, n=308) and under furniture (40.4%) predominantly in bedrooms (40.4%) and living rooms (24.8%) while *Ae. albopictus* preferred to rest on outdoor vegetation

46%(n=460). The majority (43.7 %; n=801) of *Aedes* mosquitoes rest 1–2 m above ground, and 34.4 % (n=399) rested 1 m or less. The host-seeking cycle of *Ae. albopictus* was bimodal, with morning peak occurring between 05:00 and 11:00 and afternoon peak between 14:00 and 19:00. While that of *Aedes aegypti* was with a minor peak between 05:00 and 09:00 and a major peak between 13:00 and 19:00.

Physicochemical parameters of mosquito breeding water changed significantly across breeding categories (Kruskal–Willi's statistics, $p < 0.05$), but not among species. Concrete slabs, temporary removals, and water storage items were the key breeding habitats of *Ae. aegypti*, while those for *Ae. albopictus* were concrete slabs, gutters, and natural habitats. Deltamethrin and malathion exposure to adults and temephos exposure to larvae of *Ae. aegypti* and *Ae. albopictus* showed a considerable geographical variation of mortality ($P < 0.001$) showing the change of mosquito susceptibility status.

There was a strong positive association between rainfall, larval vector density, and the likelihood of high dengue incidence. When Breteau Index for *Ae. aegypti* (BIA) exceeds 3.00 and relative humidity exceeds 80%, an early epidemic alert is triggered while BIA > 6.0, case incidence reached an epidemic level in urban areas. In suburban areas, when BI for *Ae. albopictus* (BIB) > 14.0 an early epidemic alert is triggered. At the BIB > 20, case incidence reached epidemic levels even in absence of *Ae. aegypti*. Case incidence exceeds the epidermic level in rural areas when the BI for *Ae. albopictus* is 10 with a one-month latency. In conclusion, area-based entomological thresholds and rational use of insecticides can be proposed for future control of rising dengue epidemics in the Gampaha district based on vector biology/bionomic related evidence through regular monitoring.

eywords,

Dengue, Ae. aegypti, Ae. albopictus, Gampaha, bionomics

xxx