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The BG-Sentinel™ trap as a suitable tool for *Aedes aegypti* surveillance in Far North Queensland, Australia

Thesis submitted by

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in January 2010

for the degree of Doctor of Philosophy

in the School of Public Health, Tropical Medicine & Rehabilitation Sciences

James Cook University

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_________________________________	February 12, 2010
Tamara S. Ball	Date

Statement on the Contribution of Others

Sections of the work presented in this thesis were completed with the assistance of other researchers. The contributions of others to this thesis and to future publishable outcomes of the research undertaken during my candidature are acknowledged below.

Nature of Assistance	Contribution	Names, Titles, and Affiliations of Co-Contributors
Intellectual support	**Editorial assistance**	Dr. Scott Ritchie, James Cook University, QLD
Financial support	**Field research, Stipend, and Grant** **Tuition fees**	Financial support for this research and my stipend was provided by the Foundation for the National Institutes of Health through the Grand Challenges in Global Health Initiative. Tuition was fully funded by an Endeavour International Postgraduate Research Scholarship.
Data collection	**Research assistance**	Dr. Petrina Johnson, Dr. Luke Rapley, and Anna Koetz of James Cook University, QLD, and the Dengue Action Response Team (DART) of Queensland Health, Cairns – Dr. Johnson, Dr. Rapley, and the DART collected container data which contributed to the CIMSiM model run in Chapter Four of this thesis. Anna Koetz assisted with mosquito dissections which contributed to Chapter 2.

Tamara S. Ball

January, 2010

Scott A. Ritchie

January, 2010

Declaration on Ethics

The research presented and reported in this thesis was conducted within the guidelines for research ethics outlined in the *National statement on Ethics Conduct in Research Involving Humans (1999)*, the *Joint NHMRC/AVCC Statement and Guidelines on Research Practice* (1997), the *James Cook University Policy on Experimentation Ethics. Standard Practices and Guidelines* (2001), and the *James Cook University Statement and Guidelines on Research Practice* (2001). The proposed research methodology received clearance from the James Cook University Experimentation Ethics Review Committee (approval number H2250).

February 12, 2010

Tamara S. Ball

Date

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In Memory of Professor Chris Curtis

List of Publications from this Thesis

Publications incorporated into the thesis:

BALL, T.S., RITCHIE, S. A. (2010) Sampling biases of the BG-Sentinel™ trap with respect to physiology, age, and body size of adult *Aedes aegypti*. *Journal of Medical Entomology* 47(4): 649-656. (Chapter 2)

BALL, T.S., RITCHIE, S. A. (2010) Evaluation of the BG-Sentinel™ trap trapping efficacy for *Aedes aegypti* in a visually competitive environment. *Journal of Medical Entomology* 47(4): 657-663. (Chapter 3)

Abstract

Aedes aegypti is the vector of dengue fever in far north Queensland where dengue outbreaks occur each year. The most recent outbreak in 2008/2009 saw all four serotypes of the virus circulating in the region with 1025 reported cases. Surveillance of the vector population is an important component of vector control and therefore dengue management. There are several tools that are currently used to measure the *Ae. aegypti* population, and like any sampling method, these tools need to be better understood and refined in order to achieve measurable outcomes in the field. The value of these tools lies in their sampling efficacy, and ultimately in how well we use them and understand the data that they produce—our ability to accurately interpret data from a very limited subsample of the field population.

Each sampling tool presents certain biases. Once these biases are defined, methods used to estimate population size and structure can be calibrated accordingly, resulting in more accurate and complex estimates of the vector population. Currently there are control strategies being developed that involve manipulation of *Ae. aegypti* in the adult stage (e.g. the use of the bacterial endosymbiont *Wolbachia* to shorten the lifespan of the vector population). These novel strategies demand adult sampling tools to measure changes in population size, structure (age, sex ratio) and ultimately the success of the program. The BG-Sentinel™ trap (BGS) is a proven tool that successfully samples the *Ae. aegypti* adult population. A series of mark-release-recapture experiments with adult *Ae. aegypti* were conducted in a large outdoor flight cage and an indoor setting in far north Queensland, to investigate the sampling biases of this particular trap. Biases were investigated across several categories, including: i) mosquito age ii) sex iii) physiological status and iv) body size. Biases were not detected across age groups or body sizes. A significant bias was detected across physiological groups: nulliparous females were recaptured at a significantly lower rate than all other groups except blood-fed parous females which were also recaptured at a low rate by the BGS. Males were recaptured at a higher rate than all groups, but only a significant difference in recapture rates was observed between males and nulliparous females. The sampling bias of the BGS is measurable and can be used to

generate more accurate estimates of the adult population and its attributes when sampling the field population.

Once the sampling biases of the BGS were defined, the efficacy of the trap within a competitive visual environment was investigated. The impact of the visual environment on trapping efficacy was of particular interest due to the visual cues used by the BGS to attract *Ae. aegypti*. Four to five day old males and nulliparous females were released into a semi-controlled room to evaluate the effect of the presence, reflectance, and distribution of surrounding harbourage sites on BGS trapping efficacy. Low-reflective (dark) harbourage sites near the BGS had a negative effect on both male and nulliparous female recapture rates. However, a more pronounced effect was observed in males. The distribution (clustered vs. scattered) of dark harbourage sites did not significantly affect recapture rates in either sex. In a subsequent experiment, the impact of oviposition sites on the recapture rate of gravid females was investigated. Although gravid females went to the oviposition sites and deposited eggs, the efficacy of the BGS in recapturing gravid females was not compromised. *Aedes aegypti* sampling in the field will mostly occur in the urban environment, whereby the BGS will be amongst oviposition sites and dark harbourage areas in the form of household items and outdoor clutter. In addition to understanding sampling biases of the BGS, estimations of the adult population size and structure can be further adjusted based on an understanding of the impact of the visual environment on trap captures. Outcomes from this suite of experiments provide us with important considerations for trap deployment and interpretation of *Ae. aegypti* samples from the BGS trap.

In order to understand what the BGS field samples convey about the field population, BGS field data were correlated with field population estimates generated by a weather-driven container-inhabiting mosquito simulation model (CIMSiM). This model uses container data as well as weather data to create a life table that estimate the daily population size of *Ae. aegypti* from the number of eggs to the number of adults. This particular model was recently validated and calibrated for this region. A widespread survey of premises over an 11ha area was undertaken in

February (wet season) and August (dry season) of 2007. This area was divided into ten ~1ha sections for which individual data were generated both from the model and from the BGS. One hundred and fifty-nine and 152 of 176 premises were inspected for containers during the wet and dry season, respectively. Sixty-seven BGS traps were set out during the wet season and 72 during the dry season over a 24h period. BGS data were correlated with the outputs generated by the CIMSiM model. A positive correlation between the BGS and the model outputs was observed during the wet season, but not during the dry season. Widespread trapping with the BGS over longer periods of time may reveal a stronger or weaker relationship between trap and model. Whatever the relationship between trap and model may be, interpretation of adult sampling data with the BGS needs to be further pursued in order to achieve measurable outcomes that can assist in achieving long term success in dengue control strategies.

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