SOURCE:

https://asmedigitalcollection.asme.org/ebooks/book/152/chapter-abstract/30936/Mosquito-Flight-Model-and-Applications-in-Malaria?redirectedFrom=fulltext

EBOOK CHAPTER

10 Mosquito Flight Model and Applications in Malaria Control

By Monday Eze, Jane Labadin, Terrin Lim

DOI: https://doi.org/10.1115/1.859735.paper10
Page Count: 6
Published: 2011

Understanding the movement pattern of mosquitoes is necessary in malaria research, especially in network modeling, which is based on the fact that the interactions between mosquitoes and human hosts (through blood sucking bites) sustain malaria transmissions. Flight attributes such as direction of flight, length of flight, determinants of flights, among others will affect the overall dynamics of the human-mosquito network. This paper reviews related works on mosquito flight behavior, gives brief treatment on how this is applied in mosquito traps technology, and as well as outlines the overall implications of mosquito flight patterns to network-based modeling. This work is part of an ongoing research project on network based modeling approach to malaria research with particular interest on the prediction of the public places that act as vector reservoirs.

Topics: Flight

 DOI: https://doi.org/10.1115/1.859735.paper10

MOSQUITO FLIGHT MODEL AND APPLICATIONS IN MALARIA CONTROL

[1]MONDAY EZE, [2]JANE LABADIN and [3]TERRIN LIM
Faculty of Computer Science and Information Technology,
Universiti Malaysia Sarawak, 94300 Kota Samarahan, Malaysia
[1]eze_monday@yahoo.com, [2]ljane@fit.unimas.my and [3]terrin@fit.unimas.my

ABSTRACT
Understanding the movement pattern of mosquitoes is necessary in malaria research, especially in network modeling, which is based on the fact that the interactions between mosquitoes and human hosts (through blood sucking bites) sustain malaria transmissions. Flight attributes such as direction of flight, length of flight, determinants of flights, among others will affect the overall dynamics of the human-mosquito network. This paper reviews related works on mosquito flight behaviour, gives brief treatment on how this is applied in mosquito traps technology, and as well as outlines the overall implications of mosquito flight patterns to network-based modeling. This work is part of an ongoing research project on network based modeling approach to malaria research with particular interest on the prediction of the public places that act as vector reservoirs.
KEY WORDS
Flight, Malaria, Network, Reservoir

1. INTRODUCTION

The flight behaviour of mosquitoes will no doubt affect the nature of interactions between the blood-sucking malaria vectors and the human hosts, a non-symbiotic relationship which sustains malaria transmission. Some of the findings by previous researchers on mosquito flights are discussed in this paper.

2. POPULATION DISTRIBUTION

Previous research on the contact structure between mosquitoes and human host indicate that rather than mosquitoes being uniformly distributed across the landscape, there is a trend towards localization. Hence a large expanse of land (eg. village, city, country, etc.) will have some hot spots with very high mosquito population, rather than uniform distribution across board. According to [1], though uniformity model could be more mathematically tractable, any such assumption will be grossly erroneous. Furthermore, [1] holds that mosquitoes have limited ranges of flight and perception, and therefore bite nearby and available hosts more than distant ones.

According to [2], the probability P of locating a host is a function of the number of available hosts in the environment N, which in turn is defined on the range of mosquito flight and perception. According to [3], malaria vectors rarely travel more than a few tens of meters throughout their life time, even though they have the capability for longer flights if the hosts or oviposition sites are not found within their environment [4].

3. ATTRACTANTS

Mosquito flight towards blood-meal host is influenced by a set of factors which include host movement, human body odor, carbon dioxide (CO2) and body temperature [5]. A modeling research [6] based on remote sensed data was used to simulate the formation and persistence of the pools constituting the primary breeding habitat of Anopheles mosquitoes, in the Sahel village of Banizoumbou, Niger. According to the researchers, emergent adult mosquitoes were modeled as mobile agents, faced with a series of environmentally influenced decisions, one of which is attraction to human population based on carbon dioxide levels.

4. MOSQUITO FLIGHT PATTERN

Research has shown that mosquito flight in search of oviposition site and human host is zig-zag (random) in nature. A recent modeling research in this area [2] was based on the zig-zag movement, which modeled virtual mosquitoes, searching for oviposition sites and blood-meal hosts in a 50m x 50m landscape. This research estimated maximal flight path of 250m/day and 500m/day for poor searchers and good searchers respectively, and a perceptual range of 25m. The researchers cited three previous works [7, 8, 9] to support the fact that the flight paths of resource-seeking mosquitoes is usually zig-zag, with subsequent changes to direct flight when the target is perceived.

An experiment was carried out in Rio de Janeiro, Brazil in December 2006 to evaluate the dispersal of Aedes aegypti female mosquitoes in an area with no geographic barriers to constrain mosquito flight. In the research [10] a total of 725 dust- marked gravid females were released and recaptured at the rate of 6.3%. The females were reported to have traveled a mean distance of 288.12 m and their maximum displacement was 690m; 50% and 90% of females flew up to 350m and 500.2m, respectively. The concluding statement of the report [10] is quoted as follows: "There was no evidence of a preferred direction during mosquito flight, which was considered random or uniform from the release point".

A recent PhD Dissertation [11] in Environmental Toxicology carried out in Texas Technical University states that female mosquitoes are attracted to carbon dioxide, lactic acid, octenol, acetone, butanone, and phenolic compounds. According to the research, the first phase of host search is a non-orientated zig-zag patterned flight in search of any of the above stimuli. When a stimulus is sensed, the flight behavior is changed and oriented towards the stimuli location.

5. MOSQUITO TRAP TECHNOLOGY

The mosquito trap technology was studied to understand the concepts upon which they operate, and to further discover how this technology leverages on the interaction (network concept) between mosquitoes and human host. The major discovery is that mosquito traps operate by providing an artificial environment that appears saturated with the attractants. On sensing this environment, mosquitoes fly in with the intention of taking blood meals, and then the trap catches them. The information reproduced in this paper on mosquito trap technology are from three major sources: product manuals, website of manufacturers and direct contact with users.

According to Kendal Group [12] the manufacturer of Triple Trap Insect Eliminator, "Many species of midges and mosquitoes do not travel far from where they hatch during their short life-cycle. Continuous use of the midge and mosquito trap in one area can literally collapse the midge and mosquito population over an area of up to 500 square meters, virtually eliminating biting insects". The fact that human beings are natural attractants to mosquitoes is due to the fact that in the process of breathing, human beings expel CO_2, heat and moisture.

The mosquitoes have sensors that are able to detect these outputs, and are attracted to the source of these changes. Capitalizing on the characteristics of mosquitoes, the manufacturer designed the Triple Trap Insect Eliminator to bring out the following three emissions [12] all of which are capable of attracting mosquitoes:

- Heat
- Certain wavelength of rays produced from ultraviolet light.
- CO_2 produced when a photocatalyst light is radiated onto the $Ti0^2$ (Titanium dioxide) coating of the funnel.

The manufacturer of Lentek Mosquito Trap [13] also reported the five attractants used to build their product as:

- Attractiveness of CO_2
- Moisture
- Body temperature
- Exclusive blue light
- Airflow

6. ATTRACTANTS AND PREFERENCES

An experiment to determine which of the two attractants (human odor and CO_2) is preferred by mosquitoes was carried out by [14]. The researchers pumped carbon dioxide into a tent, and human odor into another tent. The human odor was reported to have been generated by leaving a human volunteer in a pit overnight. The result was that only few mosquitoes drifted to the carbon dioxide tent, while many mosquitoes moved to the human odor infested tent. Even when the researchers increased the carbon dioxide content, there was no observed increased drift towards the carbon dioxide baited tent.

7. IMPORTANT DEDUCTIONS

From previous works reviewed, there is a common agreement by researchers that mosquito flight pattern is zig-zag (random), until they sense the presence of attractants. On sensing the attractants, they revert to directional flight towards the attracted object or condition. Some researchers have also mentioned that mosquitoes do not travel far from their breading sites [1,3].

The fact that mosquitoes do not travel so far within lifetime can be strongly reinforced by the concept of zig-zag movement. The case of an object in a one-dimensional zig-zag motion is simplistic, and has been shown to give an expected net displacement of zero [15]. This can be proved by looking at the free movement of an object in a calibrated line. Imagine a one-dimensional line calibrated as shown in Fig.1.

Authors: Monday Eze, Jane Labadin, Terrin Lim, 2011 DOI: https://doi.org/10.1115/1.859735.paper10

.... _______________________________ . . .
-2 -1 0 +1 +2

Fig.1 A one dimentional line.

Supposed that the object can independently move either left or right with equal probability $p = 50\%$. It is assumed that the object travels equal displacement such as ± 1 or ± 2 or $\pm 3\ldots$ displacement units on each forward/backward move. Hence, this experiment is reduced to a Bernoulli Trial, similar to the toss of a coin which results in "*head*" or "*tail*".

Let S_N be the number of successes, and F_N the number of failures in N Bernoulli trials with probability p for success and q for failure on each trial. Then the expected number of successes is $S_N = Np$, and expected number of failure is $F_N = Nq$, where Success = "*move rightwards*", and Failure = "*move leftwards*". Since $q = p$, then expected number of failure is the same as the expected number of success. Hence, the expected net displacement from a starting point is *zero*.

Though the movement of mosquitoes is not as direct as a one dimensional case, it can be simplified with some known facts. One fact is that if mosquitoes move in a zig-zag fashion, then they will be involved in a series of multidirectional, rather than single directional flights. In a single-directional flight, one can easily take a mosquito away from the vicinity unlike in a zig-zag flight. The presence of attractants (human beings) within the vicinity further implies that directional movements will always be directed towards the attractant. The overall implication is that mosquitoes will not move quite far from the public places, but are confined within the vicinity of the public places. A pictorial illustration of this is shown in Fig.2.

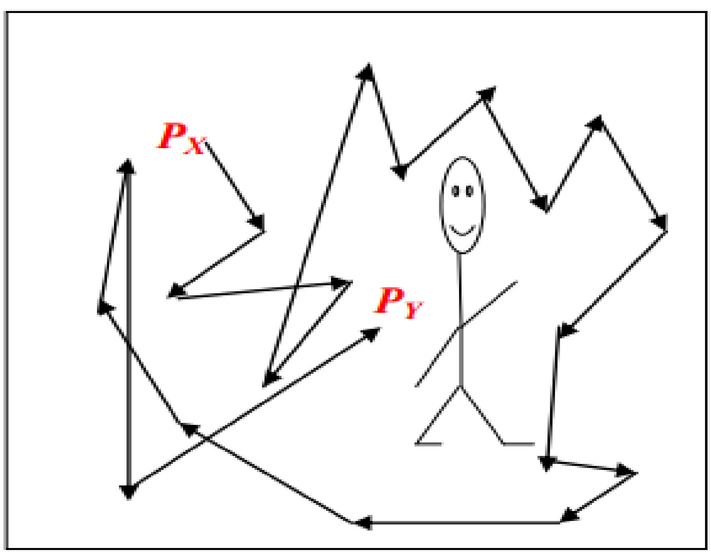

Fig.2 Mosquito in Zig-Zag flight, attracted towards a human host.

As depicted in Fig.2, an imaginary mosquito within a public place leaves its resting place PX and begins zig-zag flight, till it gets to PY while being attracted to a human host.

8. CONCLUSION

It can be concluded that the effect of migration of mosquitoes is very low compared to that of human beings in malaria transmission. Human beings travel very long distances, travelling from one part of the world to another within a short time interval unlike mosquitoes. Any network based modeling with the aim of estimating the density of mosquitoes in a given area will not be affected so much by mosquito migration as much as it will by human movements. This conclusion assumes that there is negligent or near zero effect of natural agents (eg. winds), and transporting agents (eg. vehicles) which have the capability of moving the mosquitoes from one location to another. Based on this finding, the ongoing network modeling research will emphasize more on the impacts of human migration in malaria transmission and control.

ACKNOWLEDGMENT

The authors acknowledge with gratitude the Ministry of Higher Education for financial support through the Fundamental research grant scheme FRGS/2/10/SG/UNIMAS/02/04

REFERENCES

[1] GU Weindong; NOVAK Robert. Predicting the impact of insecticide-treated bednets on malaria, transmission: the devil is in the detail, Malaria Journal [J], 2009. 8, PP256

[2] GU Weidong; JAMES Regens; JOHN Beier; ROBERT Novak. Source reduction of mosquito larval habitats has unexpected consequences on malaria transmission. Proc Natl Acad Sci USA 2006, PP17560-17563.

[3] LAURA Harrington; THOMAS Scott; KRIANGKRAI Lerdthusnee; RUSSELL Coleman; ADRIANA Costero; GARY Clark; JAMES Jones; SANGVORN Kitthawee; PATTAMAPORN Kittayapong; RATANA Sithiprasasna; JOHN Edman. Dispersal of the dengue vector Aedes aegypti within and between rural communities. Am J Trop Med Hyg [J], 2005.72, PP209–220.

[4] LIEW Christina; CF Curtis. Horizontal and vertical dispersal of dengue vector mosquitoes, Aedes aegypti and Aedes albopictus, in Singapore. Med Vet Entomol [J], 2004.18, PP351–360.

[5] ARNAUD Menach; MCKENZIE Ellis; ANTOINE Flahault; DAVID Smith. The unexpected importance of mosquito oviposition behaviour for malaria: non-productive larval habitats can be sources for malaria transmission, Malaria Journal [J], 2005. 4, PP23

[6] ARNE Bomblies; JEAN-BENARD Duchemin; ELFATIH Eltahir. Hydrology of malaria: Model development and application to a Sahelian village, Water Resources Research [J], 2008.44, PP12-445

[7] KALMUS H; HOCKING B. Behaviour of Aedes Mosquitos in relation to Blood-Feeding and Repellents , Entomol Exp Appl [J], 1960.3, PP1–26.

[8] PT Haskell. Flight Behaviour, Symp. Roy. Entomol. Soc. Lond[J], 1966.3, PP29-45

[9] SUTCLIFFE James. Distance orientation of biting flies to their hosts, Insect Sci. Applic [J], 1987.8, PP611-616

[10] RAFAEL Maciel-de-Freitas; RICARDO Lourenco-de-Oliveira. Presumed unconstrained dispersal of Aedes aegypti in the city of Rio de Janeiro, Brazil, Rev Saudi Publica [J], 2009.43.1, PP8-12

[11] CARRIE Marie Bradford. Effect of Weather on Mosquito Biology, Behaviour and Potential for West Nile Virus Transmission on the Southern High Plain of Texas, (a PhD Dissertation in Environmental Toxology), Texas Tech University, 2005

[12] KENDAL Group. http://www.hubers.co.za/

[13] LENTEK. Lentek Mosquito Trap, http://www.home-mosquito-control.com/

[14] LEG Mboera; BGJ Knols; W Takken; DELLA Torre. The response of Anopheles gambiae s.i. and A. Funestus (Diptera: Culicidae) to tents baited with human odor and carbon dioxide in Tanzania. Bulletin of Entomological Research, [J], 1997. 87, PP173-178.

[15] WIKIPEDIA, Random Walk
http://wapedia.mobi/en/Random_walk