*J Vector Borne Dis* 50, June 2013, pp. 121–126

# Effect of land use and land cover modification on distribution of anopheline larval habitats in Meghalaya, India

Atin K. Srivastava[1], B. Kharbuli[1], D.S. Shira[1] & A. Sood[2]

[1]*Animal Physiology Laboratory, Department of Zoology,* [2]*Department of Geography, North Eastern Hill University, Shillong, India*

## ABSTRACT

*Background & objectives:* The Meghalaya region had been considered free of malaria, but recently malaria cases in the foothills and valley areas raised concern that malaria transmission at high elevations may be increasing. This increase is associated with land use and land cover (LULC) changes. This LULC directly modifies larval habitats and affect the anopheline larval distribution patterns.

*Methods:* In this survey, effects of LULC changes on the distribution of anopheline larval habitats in Meghalaya over a three year period (April 2008 to March 2011) was observed. Mosquito density and diversity of neighbouring four villages located along natural swamps (less disturbed) were compared with 16 villages located near disturbed area (cultivated area, urban area, pastures land area and national highway area).

*Results:* The association between LULC type and occurrence of anopheline larvae was statistically significant. The distribution of anopheline positive habitats varied significantly between seasons. The mean density of *Anopheles* was significantly higher in urban area in all the seasons, but higher in farm land and pasture land areas only in rainy and post-rainy seasons. The six most common species collected were *Anopheles maculatus* (19.2%), *An. vagus* (13.7%), *An. annularis* (9.1%), *An. philippinensis* (8.1%), *An. barbirostris* (5.1%) and *An. minimus* (4.6%). LULC changes occurred mainly in valleys and National Highway Development Programme Phase III site. Overall, open forest area, farm land area and national highway development project phase area were observed to increase by 2.9, 1.7, and 2.1% respectively.

*Interpretation and conclusion:* Our results indicate that LULC changes in the study area were favourable to *Anopheles* larval development, increasing the risk of the spread of malaria vector habitats and malaria transmission to non-malarious regions of Meghalaya.

**Key words** Land cover; land use; malaria; Meghalaya; survey

## INTRODUCTION

In Meghalaya, incidence of malaria is increasing significantly from the year 2001. A series of epidemic seasonal malaria outbreaks had occurred in these areas in the past decade. These outbreaks caused 29,710 (average) clinical attacks annually. In Meghalaya, *Plasmodium falciparum* accounts for 93% of the total malaria cases. More than 75% of all the cases in Meghalaya had been observed in Garo Hills area (East, West, and South Garo Hills district). The annual average prevalence of malaria in India is 106 per 100,000 population, whereas in Meghalaya it is 920 per 100,000 population, which is 8.6 times more than the national average. The prevalence rate of malaria in Meghalaya is highest in the northeastern states and second in India[1]. The incidences of malaria were prevalent in foothills and valleys of Meghalaya, but now it is gradually spreading to the highland areas of the state. The main cause for this rise in infection is land use and human settlement pattern.

In the last decade, Meghalaya experienced rapid human population growth. This unprecedented increase in human population in Meghalaya induced dramatic changes in land use and land cover (LULC) and human settlement patterns[2]. This type of unplanned land use divides lands into small land patches[3, 4] and alters elements of local ecosystem such as soil character, pH, ecology of local flora and fauna and most important surrounding area temperatures[5, 6]. Although these land patches are situated in the same locality, each has a different environmental character[3]. In each patch, several types of resources are available to malaria vectors[7] and all the malaria vectors are more sensitive to these environmental changes. Their survival rate, density and distribution are dramatically influenced by different types of environmental changes, such as temperature, humidity, and availability of suitable breeding sites[8–11].

Several hypotheses and studies suggested that these LULC changes have influenced malaria vector larval habitat availability, productivity, density and distribution in the world[12–16]. Some of the subsequent studies in Meghalaya observed changes in local malaria incidences and prevalence due to mosquito resistance[17] and density change[18–20]. No studies have investigated the effect of landscape changes on anopheline species density and diversity particularly in Meghalaya. Therefore, the focus of this study was to determine land use effects on the distribution of anopheline larval habitats.

## MATERIAL & METHODS

*Study area*

The study was conducted in 20 villages of four districts in Meghalaya (East Garo Hills, West Garo Hills, South Garo Hills and Ri-Bhoi). Geographically the area lies between geo-coordinates 25°09′ 30″ N to 26°01′ 42″ N and longitudes 89°51′ 25″ E to 92°50′ 37″ E and surrounded by malaria endemic areas: Asom (north and east) and Bangladesh (south and west) (Fig. 1). The elevation of the study site was in the range, 100–1100 m. The average monthly minimum temperature was 13.8°C (8–16.2°C) and maximum temperature 23.7°C (20.3–31°C); the hottest season during May–July and the coldest season during December–February. The annual rainfall varied of 2300–11436 and an average of 321 mm. According to the 2011 national census[21], population growth of Meghalaya was 706,810 (30.65%) in the past decade. The study area included a mosaic of land use types. A natural forest was located in the western part as a form of patch and constituting approximately 12%[22].

*Selection of land use sites*

Land use in Meghalaya was initially classified into two broad categories, natural (essentially consisting areas with typical natural vegetation (NFA) covers, with little or no human interference) and artificial. The artificial land use type was further subdivided into following categories: Farm land area (FLA); Urban land area (ULA); Pasture land area (PLA); and converted or Open forest area (OFA). Five sites were selected from each district and each site representing a land use category (NFA, FLA, ULA, PLA and OFA)[23].

*Determination of LULC changes*

The LULC change detection was achieved by using prepared LULC maps 2008–11, procured from ISRO's new web portal "Bhuvan". The maps were re-projected using Erdas Imagine 9.1 (Leica Geosystem Geospatial Imaging, LLC) software to give map properties to the images. The verification of these land use types was done through field surveys in both the rainy as well as dry seasons for three years 2008–11, using handheld global positioning system (GPS) devices (Garmin 12). The geographical rectified image of each year was re-digitized to obtain polygons for the respective classifications of LULC. This was on the basis of spectral signature of each of the five classes (mentioned above) using ArcGIS 9.2 software (ESRI). In order to calculate the area of each class of LULC map, the calculated geometry function in attribute table of ArcGIS 9.2 software was used. The changes in LULC of each class were obtained by comparing the area in 2008 with that in 2011; these changes were presented graphically (Figs. 2a–c).

*Larval habitat characterization*

Environmental variables recorded for each habitat were: size, water temperature, pH, dissolved oxygen, water surface area, water turbidity, distance from colony, canopy cover, aquatic animals and substrate type. Substrate type was classified as muddy, sandy with gravel and soil, and artificial without soil. Water pH, temperature, conductivity, dissolved oxygen, turbidity, and light

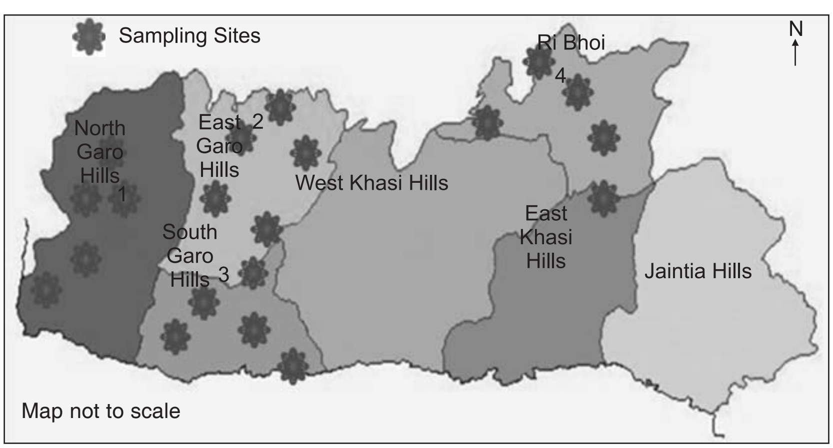
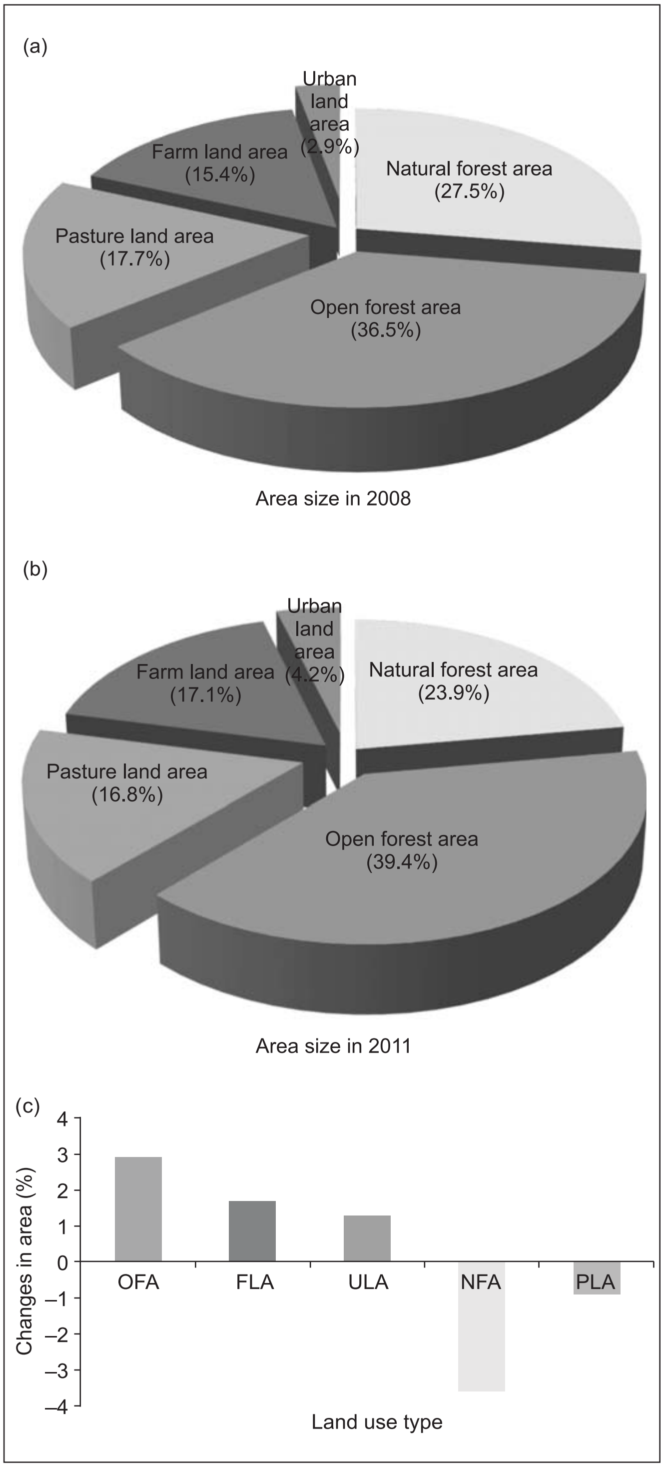



*Fig. 1:* Map showing sampling of the study area of Meghalaya region.




Figs. 2 (a–c): Land use and land cover changes in Meghalaya: (a) 2008; (b) 2011; and (c) 2008 and 2011.

intensity of larval habitat were recorded by means of a portable meter.

*Larval habitat survey and mapping*

For *Anopheles* larvae habitat mapping, surveys (in all the above mentioned villages) were conducted three times annually during the years 2008–09 and 2010–11. For the purpose of the survey, the year was divided into three phases, i.e. pre-monsoon, monsoon and post-monsoon. In each sampling season, all the aquatic habitats (including water containers in and outside of the houses) were systematically searched and their locations recorded by handheld GPS. The length and width of each habitat were measured. Land cover type and habitat locations were classified for the aforementioned five categories. Each aquatic habitat was examined for the presence of anopheline larvae using standard dipping techniques as described by Service[24]. The number of dips taken from each habitat was dependent on the perimeter of the larval habitat. Larvae and sample of water from each larval habitat were placed in plastic bags and transported to the laboratory for further processing. Anopheline larvae were separated from *Culicine* larvae and identified to species using the taxonomic keys of Gillies and Coetzee[25].

*Meteorological data*

In each village, one thermometer and relative humidity data loggers (Onset Computer Corporation, Bourne, MA, USA) were placed and one person was appointed to record temperature and humidity daily over a period of three year. Rainfall data were collected from the Meteorological Department of India.

*Statistical analyses*

All data were tested for significance by one-way analysis of variance (ANOVA), where significant differences were observed in an ANOVA test, the Tukey's honestly significant difference test was used to separate the means.

## RESULTS

*Percent changes in land cover area during study period*

The contribution of each land use type to the total LULC area of the study area in 2008 and 2011 is depicted in Figs. 2a & b, respectively. In 2008 OFA was the major land use type (36.5%) followed by NFA (27.5%), PLA (17.7%), FLA (15.4%) and ULA (2.9%) respectively (Fig. 2a). In 2011, OFA increased to 2.9%, FLA 1.7% and ULA 1.3%; NFA and PLA declined to 3.6 and 0.9% respectively (Figs. 2b and c). Maximum reduction occurred in NFA, reduced to 1220 km$^2$ (3.6%) and maximum increase in OFA 721.23 km$^2$ (2.9%). These LULC changes occurred along the rural/urban areas.

*Anopheline species composition and relative abundance*

A total of 16,004 larvae and 26 species of anopheline were collected from the selected sampling sites during 2008–11. The highest prevalence was in *An. maculatus* (15.32), followed by *An. annularis* (11.7), *An. philippinensis* (9.67), *An. nigerrimus* (5.8), *An. subpictus* (4.67) and *An. minimus* (3.51%). The other 20 species comprised >50% of the total collection. The abundance of larval species increased during the rainy season and peaked in October annually. The number of species collected from different LULC types in different seasons varied significantly ($p$ <0.05). The highest number of species found during April and May (n = 17), while only five species were found in November.

*Description and distribution of larval habitats*

From 2415 habitats investigated, 861 (35.7%, $p$ <0.01) were *Anopheles* larval habitats, and 461 (19.1%, $p$ <0.01) of these habitats had anopheline larvae only. Anopheline and culicine larvae were found in 1128 (46.7%, $p$ <0.01). A total of 19,287 anopheline larvae were collected and mapped from 2415 larval habitats, which were categorized into five types. The association between the occurrence of anopheline larvae and land cover was significant ($p$ <0.05) during the rainy season. In FLA and PLA highest numbers of anopheline larval habitats were found during rainy season (25.3% of all) and least habitats were recorded in FLA and PLA during spring season. In ULA, habitat number was about same in all the seasons. One-way ANOVA revealed that larval density of anopheline was significantly correlated with rainfall ($F_{8, 35} = 4.23$; $p$ <0.002). The proportion of mosquito positive habitats was significantly higher in ULA (66.1%, $p$ <0.01). The association between LULC and anopheline positive habitat was significantly different in all the seasons. Overall, the highest anopheline larval habitat was found in ULA (51.1%) and FLA (46.4%), followed by PLA (29.1%) and OFA (25.7%). NFA had least number of *Anopheles* larval habitats (10.8%) (Table 1).

## DISCUSSION

The climate of all the three districts of Garo Hill along with Ri-Bhoi is not very healthy, i.e. highly humid and hot as compared to other districts of Meghalaya, which is favourable for mosquitoes. There were massive changes in these areas in the past two decades: 2-fold increase in the population, more transportation and communication with other regions, shifts in land use patterns and rise in mean annual temperature; each of these changes could affect the density and distribution patterns of Anopheline[8, 15, 26, 27]. Urbanization, reforestation and deforestation have produced major changes in land use and land cover in this area. The state land use policy may affect the mosquito density and abundance in several ways[28]; more man-made aquatic habitats become available for the *Anopheles* species, the physical and chemical properties of mosquito larva habitats may change.

The results of this survey demonstrate that land cover modification affect the availability and suitability of aquatic habitats for Anopheline larvae and canopy cover was the only factor significantly associated with the occurrence with *Anopheles* larvae. Similar results have been compiled by Minakawa *et al*[29]; Lindblade *et al*[6]; Lindsay and Martens[12]; and Gimnig *et al*[30]. Open aquatic habitats occurred more often in FLA and ULA than the NFA and OFA. Therefore, productivity of *Anopheles* mosquitoes was significantly higher in FLA and ULA compared with NFA and OFA. Mosquito growth rate was significantly ($p$ <0.05) high in FLA habitat compared to other land cover because water temperature of FLA was higher. It is known that, cultivated swamps and urban aquatic habitats generally receive more exposure to sunlight than those in natural swamps, the ambient air temperature in the cultivated swamp and urban areas was significantly higher. Farmers' activities also increased habitat numbers in farmland[31]. During the rainy season, emergent aquatic plants grow considerably and make shade over aquatic habitats,

Table 1. Distribution of anopheline larvae in habitats

| Habitats | Number of habitat | Larval habitat types | | | | |
|---|---|---|---|---|---|---|
| | | NFA | OFA | PLA | FLA | ULA |
| Mosquito positive | 1228 (50.8) | 118 (15.6) | 189 (36.2) | 219 (46.2) | 287 (66.1) | 415 (69.1) |
| Anopheline positive | 861 (35.7) | 82 (10.8) | 134 (25.7) | 138 (29.1) | 287 (46.4) | 307 (51.1) |
| Only Anopheline positive | 461 (19.1) | 38 (5) | 51 (9.7) | 61 (12.8) | 114 (26.3) | 179 (29.8) |
| Mosquito negative | 1188 (49.2) | 638 (84.4) | 333 (63.7) | 255 (53.8) | 148 (34) | 186 (30.9) |
| pH | – | 6.5–7.1 | 6.6–7.3 | 6.8–7.3 | 6.8–7.2 | 6.9–7.2 |
| No. of larvae per dip | – | >10 | >23 | >41 | >39 | >60 |
| Total habitats | 2415 | 756 (100) | 522 (100) | 474 (100) | 434 (100) | 601 (100) |

Figures in parentheses indicate percentages.

which make the habitat suitable for mosquito breeding[32]. The most common aquatic habitats in farm land are rice plant nursery, drainage and ditches.

Occurrence of the anopheline larvae in urban aquatic habitats may result from a combination of several factors but our survey suggests that three factors are important for successful development of *Anopheles* larvae. First, this habitat is situated very near to feeding and resting place of anopheline mosquitoes, larval predation is less prevalent in permanent urban habitats than permanent habitat of farmland and forest land[33–36]. High water and atmospheric temperature are characteristic of ULA. Warmer temperatures, resulting from dryness of the aquatic habitat during day time shorten larvae - pupae development time and larval mortality[37, 38]. The anopheline mosquitoes may have evolved to selectively utilize these favorable conditions. In lowland urban areas of Meghalaya, water temperature of artificial container and water tank temperature (summer season) reach 35°C. *Anopheles* mosquitoes tolerate relatively high water temperature[39]. In addition, warm temperature may allow more micro organism to grow, which provide food for mosquito larvae[40].

Meghalaya highlands were originally heavily forested, providing an environment unfavourable to *Anopheles* mosquito. Clearance of the forest for agricultural activity or urbanization provided suitable mosquito breeding sites. Thus, deforestation was one of the reasons for increased mosquito in Meghalaya.

In conclusion, the results of this survey support the hypothesis that recent LULC changes in Meghalaya provide suitable habitat conditions for *Anopheles* mosquitoes. Deforestation and unplanned urbanization creates suitable habitats for *Anopheles*. This information from survey improves our understanding of LULC effects on anopheline ecology and may be useful in formulating new and effective malaria control programmes in Meghalaya.

## REFERENCES


1. Delhi India: National Vector Borne Disease Control Programme. Available from: [*http://www.nvbdcp.gov.in /malaria*], (accessed on July 1, 2012).
2. Minakawa N, Munga S, Atieli F, Mushnzimana E, Zhou G, Githeko AK, *et al*. Spatial distribution of anopheline larval habitats in western Kenyan highlands: Effects of land cover type and topography. *Am J Trop Med Hyg* 2005; *73*(1): 157–65.
3. Kitron U. Landscape ecology and epidemiology of vector-borne diseases: Tools for spatial analysis. *J Med Entomol* 1998; *35:* 435–45.
4. Stoop CA, Gionar YR, Shinta, Sismadi P, Rachmat A, Elyazar I, *et al*. Remotely-sensed land use patterns and the presence of *Anopheles* larvae (Diptera: Culicidae) in Sukabumi, west Java, Indonesia. *J Vector Ecol* 2008; *33*(1): 30–9.
5. Yasuoka J, Levins R. Impact of deforestation and agricultural development on anopheline ecology and malaria epidemiology. *Am J Trop Med Hyg* 2007; *76*(3): 450–60.
6. Lindblade KA, Walker ED, Onapa AW, Katungu J, Wilson ML. Land use change alters malaria transmission parameters by modifying temperature in a highland area of Uganda. *Trop Med Int Health* 2005; *5:* 263–74.
7. Brownstein JS, Skelly DK, Holford TR, Fish D. Forest fragmentation predicts local scale heterogeneity of Lyme disease risk. *Oecologia* 2005; *146:* 469–75.
8. Reiter P. Climate change and mosquito-borne disease. *Environ Health Perspect* 2001; *109:* 141–61.
9. Collinge SK, Johnson WC, Ray C, Matchett R, Grensten J, Cully JF, *et al*. Landscape structure and plague occurrence in black-tailed prairie dogs on grasslands of the western USA. *Landscape Ecol* 2005; *20:* 941–55.
10. Turner MG. Landscape ecology: What is the state of the science? *Annu Rev Ecol Evol Syst* 2005; *36:* 319–44.
11. Hakre S, Masuoka P, Vanzie E, Roberts DR. Spatial correlations of mapped malaria rates with environmental factors in Belize, central America. *Int J Health Geog* 2004; *3:* 1–6.
12. Lindsay SW, Martens WJ. Malaria in the African highlands: Past, present and future. *Bull World Health Organ* 1998; *76:* 33–45.
13. Okogun GRA, Anosike JC, Okere AN, Nwoke BEB. Ecology of mosquitoes of Midwestern Nigeria. *J Vector Borne Dis* 2005; *42:* 1–8.
14. Mouchet J, Manguin S, Sircoulon J, Laventure S, Faye O, Onapa AW, *et al*. Evolution of malaria in Africa for the past 40 years: Impact of climatic and human factors. *J Am Mosq Control Assoc* 1998; *4:* 121–30.
15. Githeko AK, Lindsay SW, Confalonieri UE, Patz JA. Climate change and vector-borne diseases: A regional analysis. *Bull World Health Organ* 2000; *78:* 1136–47.
16. Munga S, Minakawa N, Zhou G, Mushinzimana E, Barrack OJ, Githeko AK, *et al*. Association between land cover and habitat productivity of malaria vectors in western Kenyan highlands. *Am J Trop Med Hyg* 2006; *74*(1): 69–75.
17. Vas Dev, Sangma BM, Dash AP. Persistent transmission of malaria in Garo Hills of Meghalaya bordering Bangladesh, North-east India. *Malar J* 2010; *9* (263): 1–7.
18. Nagpal BN, Sharma VP. Survey of mosquito fauna of North-eastern region of India. *Indian J Malariol* 1987; *24*: 143–9.
19. Malhotra RP Mahanta HC. Check-list of mosquito of Northeast India (Diptera: Culicidae). *Oriental Insects* 1994; *28:* 125–49.
20. Dutta P, Khan SA. Mosquito fauna of Northeast India with special reference to the medically important vectors. *RMRC Project Report* 1995. [cited 2011 Mar 26]. Available from http://www.icmr.nic.in/000515/project.html.
21. Census of India 2001–Series-18, Provisional Population Total Paper-1 of 2011. [cited 2012 Feb 08]. Available from http://censusindia.gov.in/2011-prov-results/prov_results_paper1_india.html.
22. *Meghalaya agricultural profile*, III edn. Meghalaya, India Press Department of Agriculture 2006; p: 1–64.
23. Olayemi IK. Influence of landuse on the fitness of *Anopheles gambiae*, the principal vector of malaria in Nigeria. Online *J Health Allied Sci* 2008; *7*(4): 1–6.
24. Service MW. *Mosquito ecology: Field sampling methods*, II edn. London: Elsevier, Chapman and Hall 1993; p. 1–900.
25. Gillies MT, Coetzee M. Supplement to the anopheline of Africa South of the Sahara (Afro-Tropical region). Johannesburg: South

Africa Institute of Medical Research 1987; *55:* 1–143.
26. Minakawa N, Mutero CM, Githure JI, Beier JC, Yan G. Spatial distribution and habitat characterization of anopheline mosquito larvae in western Kenya. *Am J Trop Med Hyg* 1999; *61:* 1010–6.
27. Oyewole IO. Awoloa TS. Impact of urbanization on bionomics and distribution of malaria vector in Lagos, southwestern Nigeria. *J Vector Borne Dis* 2006; *43:* 173–8.
28. Walsh JF, Molyneux DH, Birley MH. Deforestation: Effects on vector-borne disease. *Parasitology* 1993; *106:* 55–75.
29. Minakawa N, Munga, S, Atieli F, Mushinzimana E, Zhou G, Githeko A, *et al*. Spatial distribution of anopheline larval habitats in western Kenyan highlands: Effects of land cover types and topography. *Am J Trop Med Hyg* 2005; *73:* 157–65.
30. Gimnig JE, Ombok M, Kamau L, Hawley WA. Characteristics of larval anopheline (Diptera: Culicidae) habitats in western Kenya. *J Med Entomol* 2001; *38:* 282–8.
31. Leishman PT, Lester PJ, Slaney DP, Weinstein P. Anthropogenic landscape change and vectors in New Zealand: Effect of shade and nutrient levels on mosquito productivity. *Eco Health* 2004; *1:* 306–16.
32. Beehler JW, Mulla MS. Effects of organic enrichment on temporal distribution and abundance of culicine egg rafts. *J Am Mosq Control Assoc* 1995; *11:* 167–71.
33. Service MW. Mortalities of the immature stages of species B of the *Anopheles gambiae* complex in Kenya: Comparison between rice fields and temporary pools, identification of predators, and effects of insecticidal spraying. *J Med Entomol* 1977; *13:* 535–45.
34. Mogi M. *Population dynamics and methodology for biocontrol of mosquitoes*. In: Laird M, editor. Biocontrol of medical and veterinary pests. New York: Praeger 1981; p. 140–72.
35. Washburn JO. Regulatory factors affecting larval mosquito populations in container and pool habitats: Implications for biological control. *J Am Mosq Control Assoc* 1995; *11:* 279–83.
36. Sunahara T, Ishizaka K, Mogi M. Habitat size: A factor determining the opportunity for encounters between mosquito larvae and aquatic predators. *J Vector Ecol* 2002; *27:* 8–20.
37. Garnham PCC. Malaria epidemics at exceptionally high altitudes in Kenya. *British Med J* 1945; *11:* 45–7.
38. Paaijmans KP, Imbahale SS, Thomas MB, Takken W. Relevant microclimate for determining the development rate of malaria mosquitoes and possible implications of climate change. *MalarJ* 2010; *9:* 1–196.
39. Haddow AJ. Measurements of temperature and light in artificial pools with reference to the larval habitats of *Anopheles (Myzomyia) gambiae* Giles and *A.* (M.) *funestus* Giles. *Bull Entomol Res* 1943; *34:* 89–93.
40. Clements AN. The Biology of mosquitoes: Development, nutrition and reproduction. Wallingford, UK: CABI Publishing 2000; p. 1–509.

*Correspondence to:* Atin Kumar Srivastava, Animal Physiology Laboratory, Department of Zoology, North Eastern Hill University, Shillong-793 022, India.
E-mail: vks_13@rediffmail.com

*Received:* 25 October 2012 *Accepted in revised form:* 19 February 2013