Spatial distribution and habitat characterization of mosquito species during the dry season along the Mara River and its tributaries, in Kenya and Tanzania

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Abstract
Background
Vector-borne diseases are increasingly becoming a major health problem among communities living along the major rivers of Africa. Although larger water bodies such as lakes and dams have been extensively researched, rivers and their tributaries have largely been ignored. This study sought to establish the spatial distribution of mosquito species during the dry season and further characterize their habitats along the Mara River and its tributaries.

Methods
In this cross-sectional survey, mosquito larvae were sampled along the Mara River, its two perennial tributaries (Amala and Nyangores), drying streams, and adjacent aquatic habitats (e.g. swamps, puddles that receive direct sunlight [open sunlit puddles], rock pools, hippo and livestock hoof prints, and vegetated pools). Each habitat was dipped 20 times using a standard dipper. Distance between breeding sites and human habitation was determined using global positioning system coordinates. The collected mosquito larvae were identified using standard taxonomic keys. Water physico-chemical parameters were measured in situ using a multipara meter. Mean mosquito larvae per habitat type were compared using analysis of variance and chi-square tests, while the relationship between mosquito larvae and physico-chemical parameters was evaluated using a generalized linear mixed model. The Cox-Stuart test was used to detect trends of mosquito larvae distribution. The test allowed for verification of monotonic tendency (rejection of null hypothesis of trend absence) and its variability.

Results
A total of 4001 mosquito larvae were collected, of which 2712 (67.8%) were collected from river/stream edge habitats and 1289 (32.2%) were sampled from aquatic habitats located in the terrestrial ecosystem about 50 m away from the main river/streams. Anopheles gambiae s.s, An. arabiensis, and An. funestus group, the

three most potent vectors of malaria in Sub-Saharan Africa, together with other anopheline mosquitoes, were the most dominant mosquito species (70.3%), followed by Culex quinquefasciatus and Cx. pipiens complex combined (29.5%). Drying streams accounted for the highest number of larvae captured compared to the other habitat types. A stronger relationship between mosquito larvae abundance and dissolved oxygen ($Z = 7.37$, $P \leq 0.001$), temperature ($Z = 7.65$, $P \leq 0.001$), turbidity ($Z = -5.25$, $P \leq 0.001$), and distance to the nearest human habitation ($Z = 4.57$, $P \leq 0.001$), was observed.

Conclusions
Presence of malaria and non-malaria mosquito larvae within the Mara River basin calls for immediate action to curtail the insurgence of vector-borne diseases within the basin. A vector control program should be conducted during the dry period, targeting drying streams shown to produce the highest number of larval mosquitoes.

Keywords
Anopheles gambiae Anopheles funestus Culex Mosquito Larval habitat Mara River Kenya Tanzani