## Environmental and spatial risk factors for the larval habitats of *Plasmodium knowlesi* vectors in Sabah, Malaysian Borneo

## ABSTRACT

Land-use changes, such as deforestation and agriculture, can influence mosquito vector populations and malaria transmission. These land-use changes have been linked to increased incidence in human cases of the zoonotic malaria *Plasmodium knowlesi* in Sabah, Malaysian Borneo. This study investigates whether these associations are partially driven by fine-scale land-use changes creating more favourable aquatic breeding habitats for *P. knowlesi* anopheline vectors. Using aerial remote sensing data, we developed a sampling frame representative of all land use types within a major focus of *P. knowlesi* transmission. From 2015 to 2016 monthly longitudinal surveys of larval habitats were collected in randomly selected areas stratified by land use type. Additional remote sensing data on environmental variables, land cover and landscape configuration were assembled for the study site. Risk factor analyses were performed over multiple spatial scales to determine associations between environmental and spatial variables and anopheline larval presence. Habitat fragmentation (300 m), aspect (350 m), distance to rubber plantations (100 m) and Culex larval presence were identified as risk factors for Anopheles breeding. Additionally, models were fit to determine the presence of potential larval habitats within the areas surveyed and used to generate a time-series of monthly predictive maps. These results indicate that land-use change and topography influence the suitability of larval habitats, and may partially explain the link between P. knowlesi incidence and deforestation. The predictive maps, and identification of the spatial scales at which risk factors are most influential may aid spatio-temporally targeted vector control interventions.