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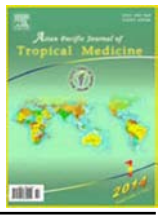

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Distribution of yellow fever vectors in Northwestern and Western Provinces, Zambia

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ABSTRACT

Objective: To determine the distribution of yellow fever (YF) vectors species in Northwestern and Western of Zambia, which sampled mosquitoes inside and outside houses in rural, urban, peri-urban and forest areas.

Methods: Back-pack aspirators spray catches and CDC light traps collected adult mosquitoes including 405 *Aedes*, 518 *Anopheles*, 471 *Culex* and 71 *Mansonia*. Morphological vector identification and PCR viral determination were done at a WHO Regional Reference Centre (Institute Pasteur Dakar), Senegal.

Results: The two main YF vectors were *Aedes* (*Stegomyia*) *aegypti* (*Ae. aegypti*) and *Aedes* (*Stegomyia*) *africanus*. The first was collected in peri-urban areas and the later was in forest areas, both sparsely distributed in Northwestern Province, where the 0.43 Breteau and 1.92 container indexes, respectively implied low risk to YF. *Aedes* (*Aedimorphus*) *mutilus*; *Aedes* (*Aedimorphus*) *minutus* and *Aedes* (*Finlaya*) *wellmani* were also found in Northwestern, not in Western Province. No *Aedes* were collected from rural peri-domestic areas. Significantly more *Aedes* species (90.7%, n=398) than *Anopheles* (9.1%, n=40) were collected in forest areas (P<0.001) or *Culex* species (0.2%, n=2) (P<0.001). *Ae. aegypti* was found only in a discarded container but not in flower pots, old tyres, plant axils, discarded shallow wells, disused container bottles and canoes inspected.

Conclusions: *Ae. aegypti* and *Aedes africanus* YF vectors were found in the study sites in the Northwestern Province of Zambia, where densities were low and distribution was sparse. The low Breteau index suggests low risk of YF in the Northwestern Province. The presence of *Aedes* in Northwestern Province and its absence in the Western Province could be due to differing ecological factors in the sampled areas. Universal coverage of vector control interventions could help to reduce YF vector population and the risk to arthropod-borne virus infections.

1. Introduction

Yellow fever (YF) is an acute hemorrhagic viral infection that is normally of non-human primates, especially monkeys[1,2]. The virus is transmitted by forest mosquitoes. Humans get infected through mosquito bites. Humans get infected when an infected monkey or mosquito enters a village or when a person enters a forest. The "yellow" in the name refers to the jaundice that affects some patients[1,2].

YF is endemic in Africa and Latin America[2]. The YF virus (YFV) circulates in both sylvatic (forest) and domestic areas, and involves various mosquitoes and vertebrate species. In the sylvatic transmission cycle, *Aedes (Stegomyia) africanus* (*Ae. africanus*) (found in Africa) or *Haemagogus* (found in America) are main vectors. In urban settings, *Aedes aegypti* (*Ae. aegypti*) is known as the main mosquito vector transmitting the YFV in Africa and South America[1]. In addition to YFV, mosquitoes transmit various

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mosquito-borne infectious agents such as filariasis, dengue virus, Japanese encephalitis virus, West Nile virus and Zika virus[3-7].

Studies have been conducted in Africa and other regions of the world on the YF vectors, regarding spatial and temporal distribution, abundance, diversity and viral isolation of mosquitoes[8-10]. In Senegal, *Ae. aegypti*, *Culex quinquefasciatus* (*Cx. quinquefasciatus*) and *Aedes furcifer* were studied and considered to be the commonest species, constituting 98% of the total collections in an area where a YF epidemic was reported[2].

Zambia provides suitable ecological and climatic conditions for mosquito vector survival. The bionomics of *Culex* species, particularly *Cx. quinquefasciatus* and *Anopheles* mosquitoes have been reported in Zambia[11]. However, documentation of the distribution of *Aedes* mosquitoes, the main YF vectors is scanty. Available data on YF vectors in Zambia dates back to the 1950s, when the country was called Northern Rhodesia[12,13]. In that period, studies were conducted on *Aedes* mosquitoes in Balovale (now Northwestern Province), Livingstone and Barotse (now Western Province), when Robinson, Bonnel and Deutschman provided general information on distribution of *Aedes* species in the sub-African region[12,13].

In 2010, Northwestern and Western Provinces of Zambia were designated as YF low risk regions by a WHO YF technical working group[14]. Limited information on the distribution of the YF vectors precluded a clear understanding on these YF vectors necessary for effective vector control. Therefore, in 2013 we conducted a study to determine the prevalence of YF vectors species in Northwestern and Western Provinces, as part of a YF risk assessment in the country.

2. Materials and methods

2.1. Description of study areas

The entomological studies were conducted in Northwestern and Western Provinces of Zambia.

Northwestern Province is located at 1 354 m above sea level, latitude −13.0 and longitude 25.0 and, has a population of 706 462[15]. The province borders with Angola on the western side and Democratic Republic of Congo on the northern side with population movement along the borders[15]. It has 6 districts. The province receives the highest rainfall in the country, with annual rainfall of 1 320 mm. The mean minimum temperature in June and mean maximum temperature in October is 6.8 °C and 30.6 °C, respectively[16]. Northwestern Province is located in Agroecological zone III which is part of the Central African Plateau. Rice, cassava, pineapples and bananas are cultivated[17].

Western Province with a population of 881 524 borders with Angola and has seven districts which were divided into 1 902 SEAs[15]. It is the driest area of Zambia and located at 1 119 m above sea level, latitude −15.0 and longitude 24.0. The province has mean minimum and maximum temperatures of 8.7 °C and 34.2 °C in June and October, respectively, and an annual rainfall of 740 mm[17]. Western Province has two main agroecological zones: major valleys as zone I and Kalahari sand plateau and Zambezi flood plains as zone II. Crop and livestock production as well as fishing are the main economic activities in the province[17,18].

Zambia experiences three seasons: the rainy season, dry cool and dry hot season. Details on rainfall patterns, elevation, mean temperatures, vegetation cover, soil types and agricultural practices in the study sites in the Northwestern and Western are described by Aregheore, 2014[17]. This study was conducted at the end of rainy season towards the dry cool season in May 2013.

2.2. Districts sampled

Mosquito larvae and adults were sampled from eight districts in Northwestern and seven districts in Western Province in rural, urban, peri-urban and forested areas and involved ecological zones described earlier and referred to in Figure 1.

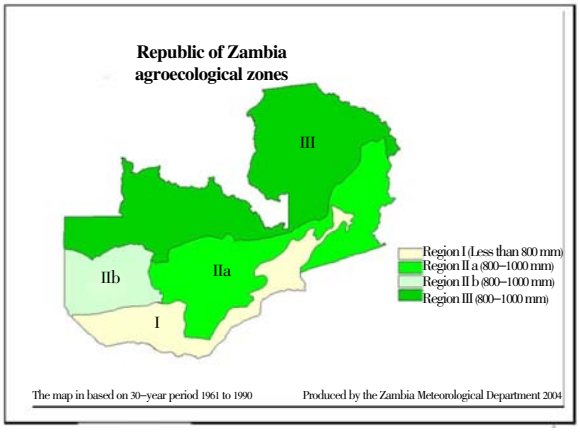

Figure 1. Agroecological zones (areas) in Zambia[19].

2.3. Mosquito larval collections

Three teams each composed of three trained researchers searched for larvae breeding sites inside and outside houses in each of the two provinces (Northwestern and Western). Each field team aimed to sample larvae in at least 10 houses per day. All water storage containers kept inside houses were inspected for mosquito larvae, while outside the houses, the following containers were inspected: flower pots, tyres, banana leaf axils, tree holes, discarded plastics, shallow wells and edges of dug-out canals. A larval scoop was used to collect larvae from different mosquito habitats outdoors. The larval collections were transferred onto a white tray, from where they were transferred with a pipette into entomological bottles labeled with date, province, district, and locality (urban or rural), and taken to an insectary at Tropical Diseases Research Centre (TDRC) for rearing into adults for initial morphological identification before sending to Institute Pasteur Dakar (IPD), Senegal for PCR species identification and virus activity determination.

2.4. Ae. aegypti larval indices analysis

To assess the entomological epidemic potential of YF disease, Breteau index (BI) on *Ae. aegypti* was estimated for the district in each province. The BI served as an indirect measure of vector density to infer epidemic risk, with BI>5 indicating risk of epidemic. The container index (CI), estimated as percentage of containers with mosquito

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