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First record of *Aedes albopictus* in inland Africa along the River Niger in Bamako and Mopti, Mali

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Abstract

The distribution of *Aedes albopictus* in Africa has thus far been known to be restricted to coastal Sub-Saharan countries. This report describes the first record of the tiger mosquito in habitats located in Mali, at a significant distance from the coastal areas of the continent. *Aedes. albopictus* was observed over several years in increasing frequency in Mopti in Central Mali and later in the capital city Bamako, both adjacent to the Niger River. These findings suggest further dissemination of *Ae. albopictus* could be facilitated by river transport of goods and commodities which harbor larvae and eggs of this species. If correct, the distribution of *Ae. albopictus* is expected to extend to areas located upstream of the Niger River and its tributaries.

Graphical abstract

The first occurrence, and possible river dissemination, of *Aedes albopictus* in inland Africa is documented from Mali along the Niger River

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Aedes albopictus collection locations

Keywords

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The vector and nuisance mosquito *Aedes albopictus* (Skuse), common name tiger mosquito, was formerly restricted to South-East Asia. Throughout the second half of the 20th century it rapidly spread to many parts of the world, with initial sightings on islands of the Western Pacific (Belkin, 1962), followed by invasion of the Americas (Reiter and Sprenger, 1987), Europe (Sabatini et al., 1990, Dalla Pozza and Majori 1992, Mitchell 1995, Knudsen et al. 1996, Romi et al., 1999) and the Middle East (Haddad et al., 2007). The first recorded sighting of *Ae. albopictus* on the African continent was reported in the early nineties in the Republic of South Africa (Cornel and Hunt, 1991). The following year, the distribution of the tiger mosquito extended to Nigeria (Savage et al., 1992), and thereafter it increased rapidly to the coastal regions of Western and Central Africa (Fontenille and Toto, 2001; Toto et al., 2003). This vast and rapid global dispersion of *Ae. albopictus* is directly linked to intercontinental trade of used tires, which constitute important larval habitats of *Aedes* mosquitoes (Reiter and Spenger, 1987; Cornel and Hunt, 1991).

Besides being a highly problematic day-biting nuisance mosquito, *Ae. albopictus* is also highly anthropophilic and a competent vector for at least 22 arboviruses, notably chikungunya and the four serotypes of dengue (reviewed by Gratz, 2004). Furthermore, though the Zika virus has yet to be isolated from wild type *Ae. albopictus*, Wong and colleagues (2013) were able to establish infections in the laboratory proving that this mosquito is a susceptible Zika vector. The spread of *Ae. albopictus* in Africa is thus very troubling, as arbovirus epidemics are becoming increasingly prevalent in many regions of the continent. In 2004, an outbreak of chikungunya was reported in Kenya (Chretien et al., 2007), and a short time later in Cameroon and Gabon (Peyrefitte et al., 2007; Peyrefitte et al., 2008), Central African Republic (Diallo et al., 2010), Cote d'Ivoire (Konan et al., 2013) and the Republic of Congo (Mombouli et al. 2013; Moyen et al., 2014). A dengue virus (DENV) serosurvey conducted in Mali in 2006 showed that 93% (87/93) of the samples obtained from the Institut National de Recherche en Sante Publique in Bamako were positive for anti-DENV IgG antibodies, with some samples neutralized monotypically against DENV-1 and DENV-2, while others neutralized broadly against multiple DENV in plaque-reduction neutralization tests (Phoutrides et al., 2011). The further spread of *Ae. albopictus* in Africa can potentially enhance the dissemination of vector-borne arboviruses like chikungunya and dengue, increasing the frequency of outbreaks and the impact on human health in countries which are already susceptible to a multitude of arthropod-borne diseases.

Our first detection of *Ae. albopticus* in Mali was in 2008, when a single female of the species was captured with a CDC trap which was positioned for 24 hours in a fishing village located on the northern outskirts of Mopti. On that occasion, further attempts to locate additional specimens of the tiger mosquito in traps or landing on human bait proved unsuccessful, indicating the species was yet to be stably established at that time. In 2010, we

again discovered *Ae. albopictus* in CDC traps and landing on human hosts around the area of Mopti, while conducting other mosquito studies (Müller et al., 2010). In surveys conducted in October 2014 we hand nets were used to collect the tiger mosquito landing on human hosts in shady areas along the river located within the city of Mopti, confirming that this species is well established in this area. In these surveys, 10 specimens were identified in the laboratory by cross-referencing with pictorial species identification keys (Rueda 2004).

Additional sightings of *Ae. albopictus* were made in Bamako. A small survey was conducted over two days in November 2012 in several neighborhoods, in which mosquitoes attempting to land on human bait were collected using entomological hand nets in the late afternoons. In this instance, we collected 125 *Ae. albopictus* in shaded areas near the Niger River. The occurrence of the tiger mosquito decreased with increasing distance from the river. About 1 km from the river, the dominant day-feeding mosquito was *Ae. Aegypti;* no specimens of *Ae. albopictus* were observed beyond this distance.

Immature stages of *Ae. albopictus* were also collected by dipping and a cooking baster. Larvae were collected and reared to maturity for subsequent identification as described above. *Aedes albopictus* larvae were found exclusively in container-type habitats found in an area spanning several hundreds of meters parallel to the Niger River. These included plastic buckets (2 out of 17 surveyed buckets), plastic bags (3 out of 50), dried-fruit containers (1 out of 29), tires (3 out of 6), marooned small boats (1 out of 8) and in water accumulated within active boats used for fishing (2 out of 5), sand transport (1 out of 7), and other goods/ human transport (2 out of 28). Samples obtained at greater distances from the river contained only 39% *Ae. aegypti* and 61% *Culex quinquefasciatus* juveniles.

These findings are the first observations of *Ae. albopictus* in land-locked Mali, at sites located more than 1000 km from any coastal regions. *Ae. albopictus* was found exclusively in habitats with close proximity to the Niger River, often in or near patches of dense vegetation, as opposed to *Ae. aegypti* which was found at both vegetated and urban sites. The high proportion of *Ae. albopictus* collected at six locations, 68.75%, (versus 31.25% *Ae. aegypti*) indicates *Ae. albopictus* populations are well established at densely vegetated sites adjacent to the Niger River.

As mentioned above, the dissemination of *Ae. albopictus* in Africa has been attributed to the thriving local trade of second hand tires (Cornel and Hunt, 1991). Mosquitoes may have arrived through several different routes to African harbors by importing used tires directly from North America, Europe and East Asia. It is feasible that transportation of such commodities has facilitated the dispersion of mosquitoes further inland. In this context, it is noteworthy that the majority of the breeding sites observed in Bamako were in close proximity of the river, mostly in containers used for shipping transport, or in puddles in leaking wooden boats. Our findings of large *Ae. albopictus* populations along the Niger river in Bamako (regular observations from 2008 until 2015) and several records from Mopti obtained through CDC trap catches and observations on human hosts (unpublished data of the authors, 2008, 2014) suggest that this species is further disseminated through boat traffic along the river. The records from Bamako and Mopti, located approximately 1000 km and 1600 km from the coast, respectively, are thus far the furthest sites *Ae. albopictus* has been

discovered from the seashore. If *Ae. albopictus* is indeed disseminated through boat traffic, it seems highly likely this species will soon be found along the entire Niger River system, and accordingly, Guinea Conakry and Niger could be the subsequent countries invaded. The results from Mali suggest a different mechanism of dissemination, possibly linked to river transport, although further research is required to prove whether this is the primary mode of dispersion that has caused this species to penetrate the interior of the continent following its arrival to the African shores.

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Highlights

- The distribution of Ae. albopictus has rapidly increased over the last decades
- Formerly restricted to coastal Africa, we have sighted the species in inland Mali
- The species seems to be exclusively located in habitats proximal the Niger River
- Larvae on small boats suggests the species may be disseminated through river traffic
- Findings suggest the species may soon spread through the entire Niger River system