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Effectiveness of a multiple intervention strategy for the control of the tiger mosquito (*Aedes albopictus*) in Spain

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ABSTRACT

This study was undertaken to evaluate the effectiveness of four complementary and combined strategies to minimize the presence of the invasive mosquito *Aedes albopictus*, firmly established in Sant Cugat del Vallès, Catalonia, Spain. A quasi-experimental design including six neighbourhoods was performed in 2008–2009. The abundance of mosquitoes was monitored through ovitraps. The multiple intervention strategy consisted of four actions: source reduction; larvicide treatments (*Bacillus thuringiensis israelensis* and diflubenzuron); adulticide treatments (alfacipermetrin); and cleaning up uncontrolled landfills. The results showed the number of eggs significantly reduced in the areas with intervention. In 2008, the accumulate median of eggs was 175 and 272 in the intervention and control areas, respectively. In 2009, these medians were 884 and 1668 eggs. In total, 3104 households were visited and 683 people were interviewed. During inspections inside the houses, the cooperation of citizens in 2009 was 16% higher than that in 2008 (95% CI 13–19%). These findings suggest that the strategy was effective in reducing the number of eggs. Citizen cooperation, an essential factor for success, was observed through a high level of collaboration by the home owners, who allowed entry into their private dwellings. This study could be a model for controlling the populations of *Ae. albopictus* in the Mediterranean region.

1. Introduction

The Asian tiger mosquito *Aedes albopictus* (Skuse 1894) (Diptera: Culicidae) is an invasive species, originally indigenous to the forests of Southeast Asia, that in recent decades has spread to many temperate and tropical regions of the world, including southern Europe.[1–3] It was detected in Spain for the first time in Sant Cugat del Vallès, Catalonia, during the summer of 2004.[4,5] *Aedes albopictus* is a synanthropic and daytime biting species. Its use of artificial containers in suburban landscapes as breeding sites was one of the reasons that contributed to its rapid geographic spread.[3] Nowadays the tiger mosquito has colonized 119 municipalities of Catalonia, affecting potentially approximately 5 million people. In Sant Cugat, *Ae. albopictus* is currently well established, becoming a major pest organism and affecting people's health and their quality of life.[6]

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The tiger mosquito is dangerous, owing to its potential implications for public health.[3,7,8] This species is capable of transmitting many diseases to humans, being an important vector of several arboviruses, such as dengue (DEN), chikungunya (CHIK) virus, yellow fever and several other types of encephalitis.[1,8,9] DEN is the most important arboviral disease in the world, affecting more than 50 million people every year. Despite *Ae. aegypti* being responsible for most cases, *Ae. albopictus* has been associated with some outbreaks of DEN.[1,8] An outbreak of CHIK fever in the summer of 2007 in northeast Italy, with 200 diagnosed cases,[10] was the first confirmation that temperate *Ae. albopictus* populations could transmit a tropical virus imported by travellers and cause an epidemic in a colonized European area, creating an important health concern.

Although a number of control strategies for mosquito-borne diseases operate in different localities and countries, integrated vector management (IVM) techniques, such as source reduction (SR, a community-based approach), pesticide application, biological control, education and public awareness, as well as personal protection seem to offer the most promising results.[7,11–13] An important point in carrying out long-term effective control is that it is necessary to include the collaboration of people who possess domestic points of breeding.[11] Several researchers advocate that SR efforts are the only sustainable way to control *Aedes* (Stegomyia) vectors.[14–17] Data show that once the tiger mosquito is established in a zone it is nearly impossible to eliminate it and very difficult to reduce the size of its population.[18]

The important spread of *Ae. albopictus* through all continents in recent decades,[1,3] the importation of active cases of CHIK and DEN,[8,19] the vectorial capacity for both viruses[20] and the vulnerability of southern Europe to virus introduction[2,21] emphasize the importance of development and application of strategies for IVM control methodologies. The aim of this study was to evaluate the efficiency of four complementary and combined strategies in the minimization of the *Ae. albopictus* population in one of the largest municipalities in Catalonia.

2. Materials and methods

2.1. Study site

The study was performed in Sant Cugat del Vallès (41°28′4″N, 1°53′49″E, 48.32 km^2; mean elevation 172 m) and the nearby municipality of Rubí (41°29′36″N, 02°01′57″E, 32.30 km^2; mean elevation 123 m). Both are residential Catalan towns (population 82 642 and 73 691 inhabitants, respectively) with many parks and large areas of single houses with private gardens, courtyards and pools. The average annual rainfall is 605 mm, and the average minimum temperature is 10.2 °C, with a typical Mediterranean climate. Sant Cugat and Rubí are located at 15 km and 20 km, respectively, northwest of Barcelona, from which both urban areas are biogeographically separated by the Natural Park of Collserola.

The six studied zones are depicted in Figure 1 and Table 1. Areas 1 and 2 had intervention for two consecutive years: 2008 and 2009. Areas 3 and 4 were used as controls during 2008, but after the city council carried out SR programmes in all houses where citizens had complained or asked for technical support, they were included in 2009 as intervention areas. Control zones (areas 5 and 6) were located in Rubí, where the tiger mosquito was detected later and the city council had not promoted any *Aedes* spp. control programmes at the time of the study.

The study areas comprised mainly single-family dwellings and were segregated from surrounding neighbourhoods by large roads, woodlands or building complexes. There were 100 to 470 houses in each neighbourhood, and the mean lot size was 0.17–0.25 ha. All housing and inhabitants in the six study areas were included, and only people who refused to participate in the study, those with mental disabilities and those <16 years were excluded.

2.2. Study design

This was a quasi-experimental study with multiple interventions, carried out from February to October in 2008 and from May to December in 2009, and consisted of four complementary strategies. The first of these was SR. House-to-house visits were carried out in each studied neighbourhood. The field workers asked for permission to enter the properties to educate the citizens about measures to prevent mosquito-borne disease. SR achieved through environmental sanitation of containers was used as a method for experimentally manipulating the production of immature *Ae. albopictus* in container habitats. As many residences as possible within neighbourhoods were surveyed for water-holding containers. In intervention areas, any water remaining in a container was discarded, and the container was turned over so that it would not collect rainwater. Any wet containers that could not be emptied were treated with an insect growth regulator larvicide (diflubenzuron 2% at a concentration of 1 g/hl) (Flower, Lleida, Spain). SR measures were conducted after adult householders gave verbal informed consent. The outcome of each visit was recorded in detail on a form and given to the city council.

The second measure was larvicide treatment with DEVICE TB2 (diflubenzuron 2% at 1 g/hl) in scuppers, water tanks and street drains containing stagnant water in the intervention areas. A granular formulation of the biolarvicide *Bacillus thuringiensis israelensis* (Bti), Vectobac G (EPA Registration No. 73049-10) (1.2% Bti, 1 g/m^2) (Valent BioSciences Corporation, Libertyville, IL, USA), was applied to seasonal streams. The third measure was sanitization of municipal sites and wooded terrains, with removal of uncontrolled rubbish dumps in the intervention zones. The fourth measure was adulticide treatment (Fastac 10% – alfacipermetrin 50 cc/hl) (Basf Española S.A., Tarragona, Spain). Monthly, from July to October 2008–2009, insecticide was sprayed on the vegetation of some public gardens of each neighbourhood study area by specialized teams. These isolated fumigations were carried out, selecting two or three points in each intervention area, and giving priority to public gardens with the greatest number of users, as well as points located centrally in the intervention area to achieve a greater effect.[22]