

## Contrat doctoral – ED Galilée

**Titre du sujet :** Mathematical study of interspecific competition in mosquito populations.

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- Discipline : Mathématiques
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- Domaine de recherche : mathématiques appliquées
- Mots clés : dynamique des populations, équations de réaction-diffusion.

### Résumé du sujet de thèse :

The fight against vector-borne diseases or arboviruses, such as dengue fever, chikungunya, and Zika, has become a public health issue even for countries in the northern hemisphere, including France, due to the invasion of certain vectors, particularly *Aedes albopictus* mosquitoes. It is well known that reducing the vector population is a very effective method of reducing the epidemiological risk. The need for better prevention of these epidemics has prompted the international scientific community to develop innovative and sustainable control strategies that are more effective and environmentally friendly.

The most successful strategies today are based on two main approaches:

- The spread of *Wolbachia*, a symbiotic bacterium, in the mosquito vector population to prevent the development of viruses (such as Dengue or Zika [Moreira2015]) and block their transmission.  
This technique, known as population replacement, has already been successfully tested in the field [Hoffmann2011].
- The repeated release of male mosquitoes (sterilized by X-rays or carrying an incompatible *Wolbachia* bacterium) to reduce or even eliminate the vector mosquito population. This technique is called the sterile insect technique.

Despite the various experimental studies that have been or will be conducted, it is not possible to take all factors into account or test all possible strategies. This is why the development of mathematical models (and their simulations), in close collaboration between mathematicians and entomologists, is essential in order to resolve or study certain issues.

Several recent studies have successfully modeled the temporal and spatial dynamics of mosquito populations using systems of partial differential equations. However, to date, very little research has focused on competition between mosquito species and its influence on the success of the above techniques. In fact, although it has been studied very little, this phenomenon of competition could have a

significant impact on the dynamics of mosquito populations. For example, it has been noted that in many tropical regions, mosquitoes of the species *Aedes Aegypti* and *Aedes Albopictus* live in very distinct environments. Furthermore, the phenomenon of satyrization has also been observed and studied in mosquitoes [Bargielowski2016].

The objective of this thesis, is to conduct a study of mathematical models describing competition between species. Systems of partial differential equations have recently been proposed in [Beck2025, BenAli2025] and will serve as the starting point for the study. These systems describe the temporal (and spatial) dynamics of juvenile and adult mosquito densities for each competing species.

The candidate must have obtained an M2R in applied mathematics and must have a keen interest in the mathematical modeling of biological phenomena, the study of PDEs, in particular reaction-diffusion systems, numerical simulation, and interaction with entomologists.

## References

[Bargielowski2016] I. Bargielowski, and L. Lounibos, Satyrization and satyrization-resistance in competitive displacements of invasive mosquito species, *Insect Science* (2016) 23, 162--174.

[BenAli2025] S. Ben Ali, M. L. Tayeb, N. Vauchelet, {\it Influence of the competition in the spatial dynamics of a population of *Aedes* mosquitoes}, *Journal of Differential Equations*, Volume 421, pp 208--240 (2025).

[Beck2025] E. Beck, L. Beuerle, P. Martin, R. Stambaugh, R. Crespo, M Robert, S Robertson, Modeling the Effects of Temperature and Resource Quality on the Outcome of Competition Between *Aedes aegypti* and *Aedes albopictus* and the Resulting Risk of Vector-Borne Disease, *Bulletin of Mathematical Biology* (2025) 87:138.

[Hoffmann2011] A. A. Hoffmann and al., Successful establishment of *wolbachia* in *aedes* populations to suppress dengue transmission, *Nature*, 476(7361) :454--457, aug 2011.

[Moreira2015] Luciano A. Moreira and al., A *wolbachia* symbiont in *aedes aegypti* limits infection with dengue, chikungunya, and plasmodium, *Cell*, 139(7), 2015.

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