Vector-borne disease outbreak control via instant vector releases

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Aedes mosquitoes: A public health problem

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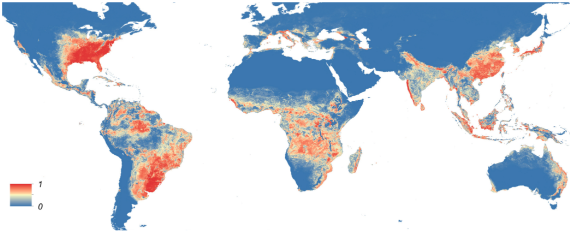
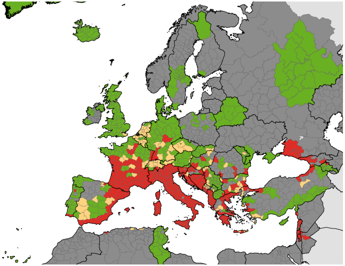
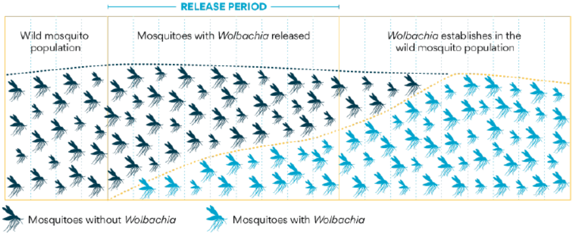
- No efficient vaccine, nor antiviral drugs.
- Expansion of vector's habitat (trade, global warming, reduction of predator populations ...)





How to fight it? Two methods

- *Wolbachia* method
  - Reduction of the vector capacity.
  - Cytoplasmic incompatibility.
  - *Wolbachia* vertical transmission.
  - Population replacement.



Source: http://www.eliminatedengue.com/our-research/Wolbachia

♀\♂	Infecté	Sain
Infecté	I	I
Sain	×	S

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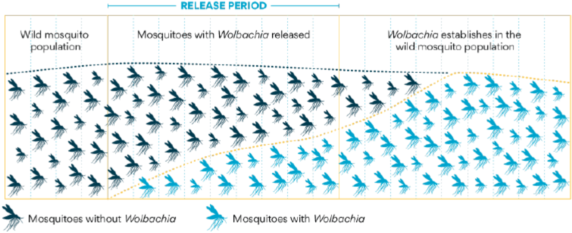

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♀\♂	Infecté	Sain
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- Sterile insect technique

  - Population suppression.
  - Recurrent intervention

The model

$$\begin{aligned} S_H' &= b_H H - \frac{\beta_M}{H} I_M S_H - b_H S_H \\ E_H' &= \frac{\beta_M}{H} I_M S_H - \gamma_H E_H - b_H E_H \\ I_H' &= \gamma_H E_H - \sigma_H I_H - b_H I_H \end{aligned}$$

$$M' = b_M M \left(1 - \frac{M}{K}\right) - d_M M$$

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Impulsive control: $u(t) = \sum_{i=1}^{n} c_i \delta(t - t_i)$ **Constraint:** $\sum_{i=1}^{n} c_i = C$

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Goal: Minimise $J(u)$ during an outbreak

$$J(u) := \int_0^T I_H(t)dt$$

Numerics

We compute $\dfrac{\delta J(u)}{\delta t_i}$ and $\dfrac{\delta J(u)}{\delta c_i}$ and we implement a numerical algorithm.

- For the t_i: Gradient descent
- For the c_i: Uzawa algorithm to deal with the constraint $\displaystyle\sum_{i=1}^{n} c_i = C$.

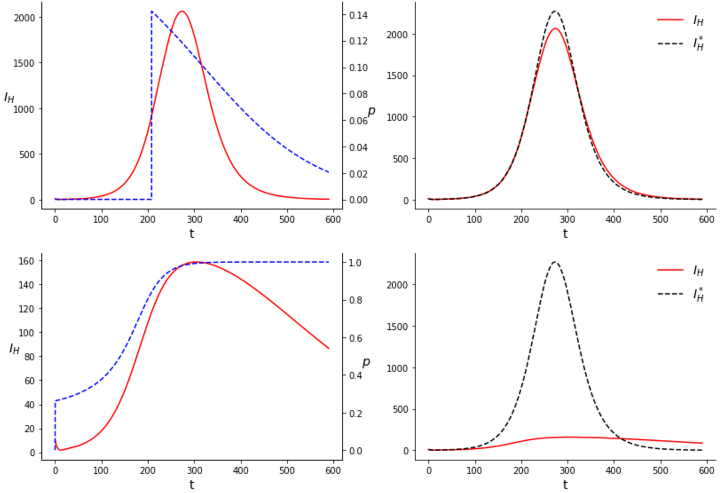
Results: Wolbachia

- $C < G(\theta)$: release before the outbreak reaches its peak.
- $C > G(\theta)$: Release at $t = 0$.

$\mathbf{C = 10000}$
Reduction:
2.0%

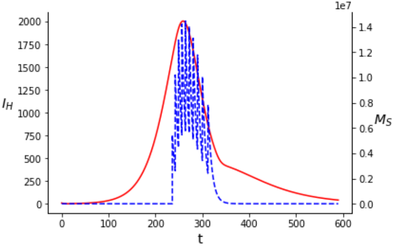
$\mathbf{C = 20000}$
Reduction:
80.3%

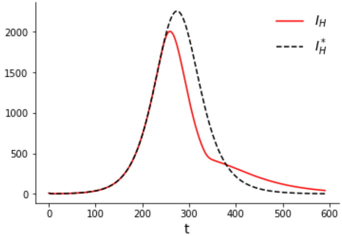
$\mathbf{G(\theta) \approx 14800}$



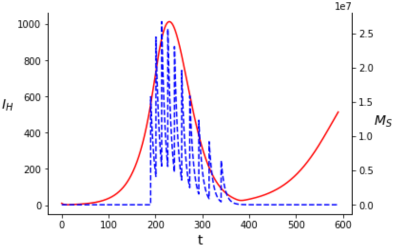
Results SIT: 10 releases

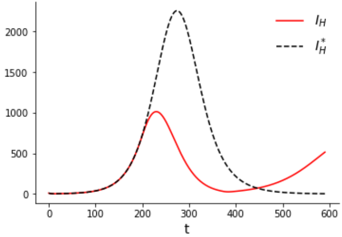
$\mathbf{C = 7.5 \cdot 10^7}$
Reduction:
12.3%





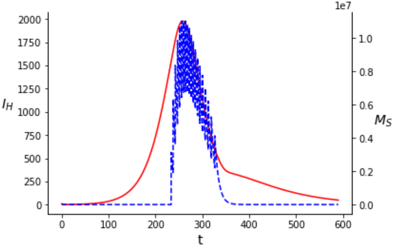
$\mathbf{C = 1.5 \cdot 10^8}$
Reduction:
49.1%

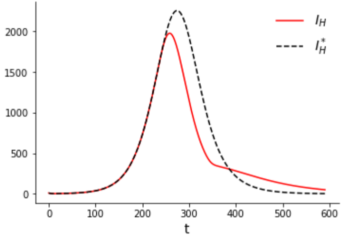




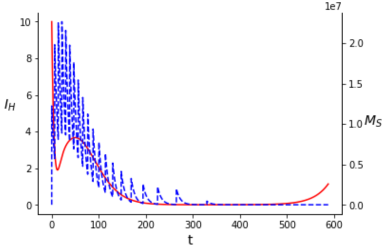
Results SIT: 20 releases

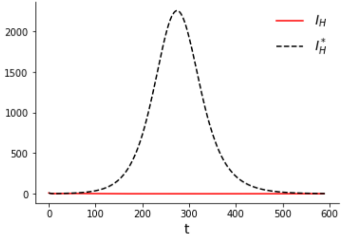
$\mathbf{C = 7.5 \cdot 10^7}$
Reduction:
13.9%





$\mathbf{C = 1.5 \cdot 10^8}$
Reduction:
99.9%





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  - After ~ 20 jumps almost no improvement.
  - With few mosquitoes: spaced releases around the peak.
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Thank you for your attention