Insecticide resistance in *Aedes aegypti* populations of New Caledonia: what is the future for vector control ?

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MiVEGEC Maladies Infectieuses et Vecteurs Ecologie, Génétique, Évolution et Contrôle

Institut Pasteur de Nouvelle-Calédonie

VILLE DE NOUMEA

DASS

Vector control and insecticides

Aedes aegypti control in Noumea :

- Prevention + *Entomological monitoring network*
- **Larvicide**
  - Destruction of breeding sites by the community
  - *Bti* (*Bacillus thuringiensis israelensis*)
  - Organophosphates : *Temephos*

Traitement par le SIPRES - Ville de Nouméa ©RSE/L.Guillaumot

- **Adulticide space spraying**
  - Pyrethroids : *Deltamethrin (+ Etofenprox)*
  - Organophosphates : *Malathion*

+ « Households » adulticides

- Pyrethroids (Permethrin, allethrin)

Vector control and insecticides

- **Neurotoxic insecticide families** :
  - Pyrethroids (PYR)
  - Organophosphates (OP)
  - Organochlorines (OC)
  - Carbamates (CAR)

Aedes aegypti

Anopheles gambiae

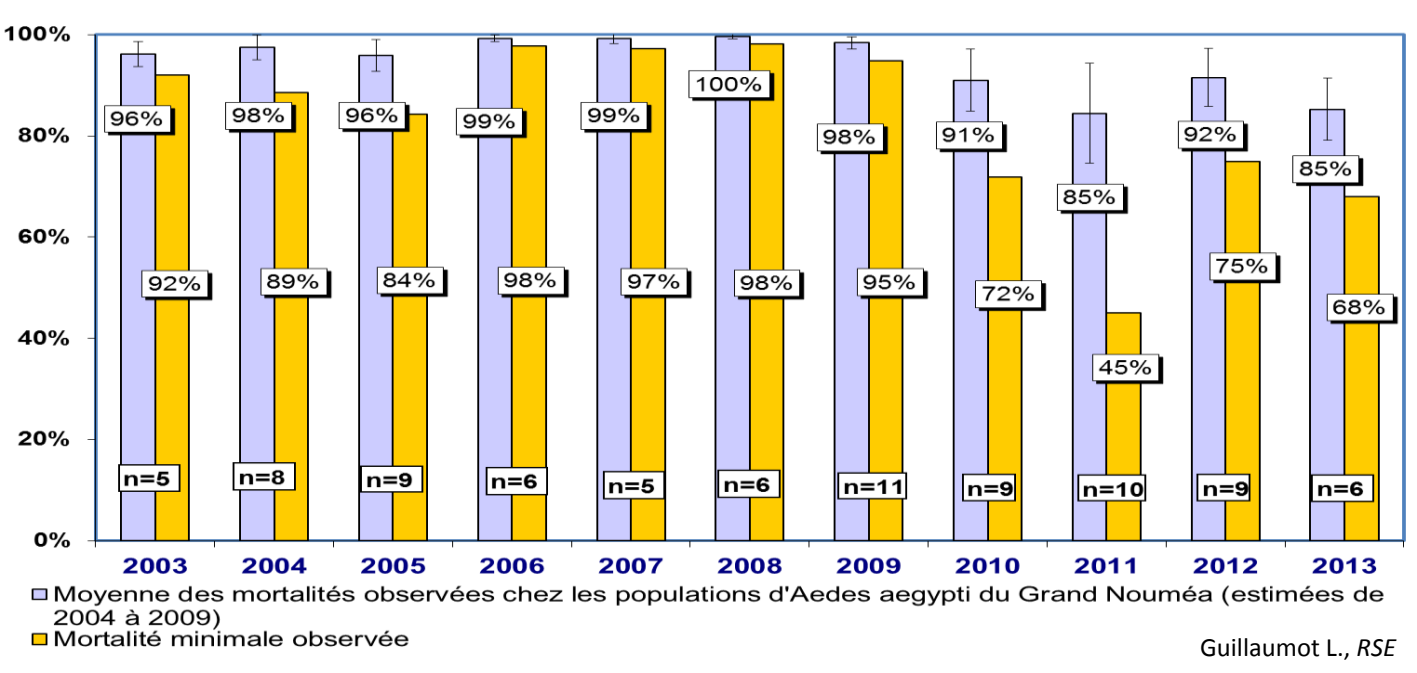

Diabrotica - corn

Selection of resistance

- To all insectide families
- In « almost » all insect species (disease vectors or agricultural pests)

Tracking susceptibility to deltamethrin in Noumea (2003 – 2013)

- 2003 - 2004 : perifocal use of deltamethrin + epidemic : ↘ susceptibility
- 2005 : non epidemic years : ↗ susceptibility
- 2007 : perifocal use of malathion + deltamethrin
- 2008 - 2009 : deltamethrin + malathion + dengue epidemic : ↘ susceptibility
- 2011 and 2013 : dengue epidemic + chikungunya outbreaks: deltamethrin + malathion



Resistance to deltamethrin → vector control strategies ?

Insecticide resistance

- **Major mechanisms for insecticide resistance**

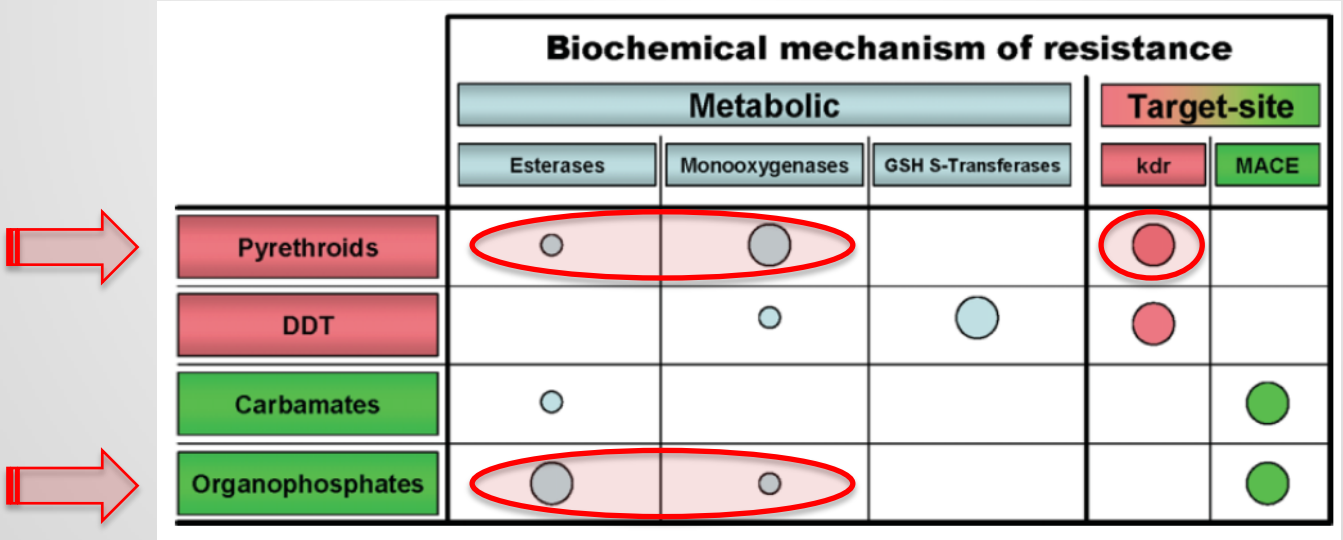
  - **Metabolic resistance = enzymatic detoxification**
    - Cytochrome P450 oxidases
    - Esterases (α and β)
    - Glutathione S-transferases (GST)
  - **Molecular resistance = target site modifications**
    - Voltage-gated sodium channel mutations (*kdr = knock-down resistance*)
    - Acetylcholinesterase mutations (AchE)

Insecticide resistance

Major mechanisms

- Metabolic resistance = enzymatic detoxification
- Molecular resistance = target site modifications

→ **Multiple and cross-resistance**



(Nauen R., 2007)

Monitoring the susceptibility / resistance to deltamethrin in Noumea

« Réseau de Surveillance Entomologique » (RSE)

- Bioassays (WHO tubes, n = 100):
  - deltamethrin 0,05%
  - malathion 5%

⇨ **No resistance to malathion :**
100% susceptibility

⇨ **Resistance to deltamethrin :**
Susceptibility in 34 populations :

- 24 populations ≤ 95%
- 7 populations ≤ 80%

Spatial and temporal distribution of *Ae. aegypti* resistance to deltamethrin in Noumea

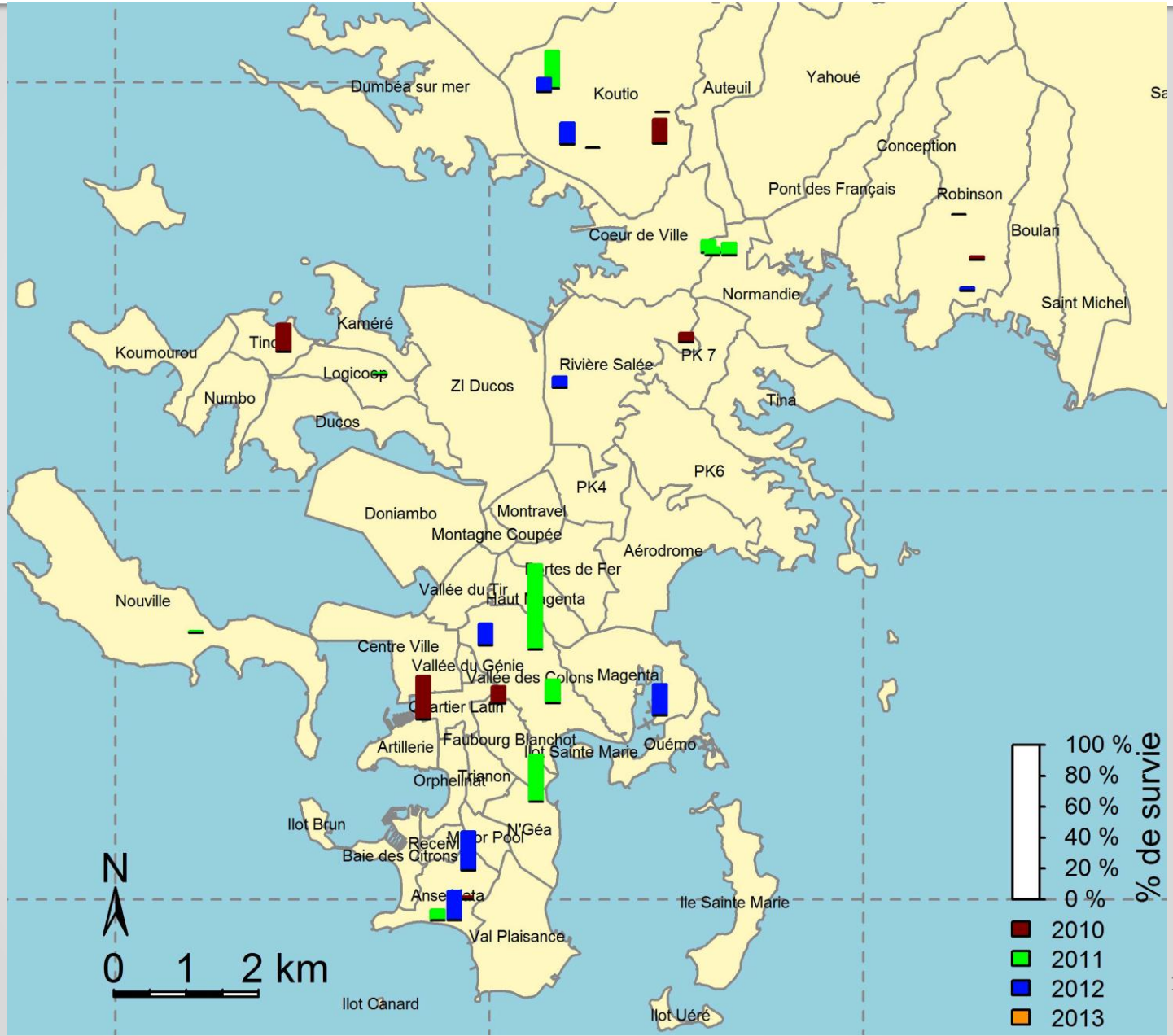
2010

Spatial and temporal distribution of *Ae. aegypti* resistance to deltamethrin in Noumea

2011

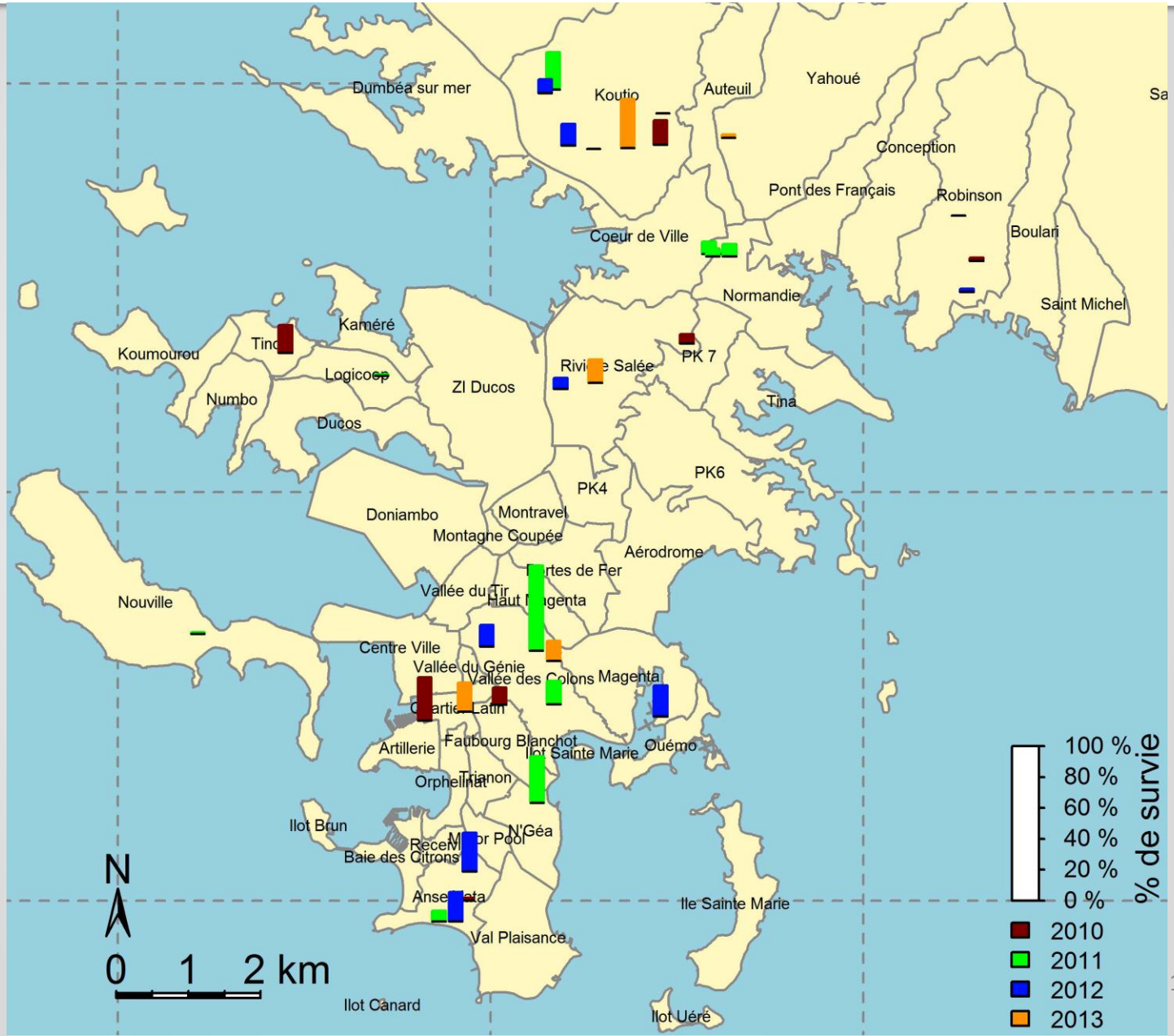
Spatial and temporal distribution of *Ae. aegypti* resistance to deltamethrin in Noumea

2012



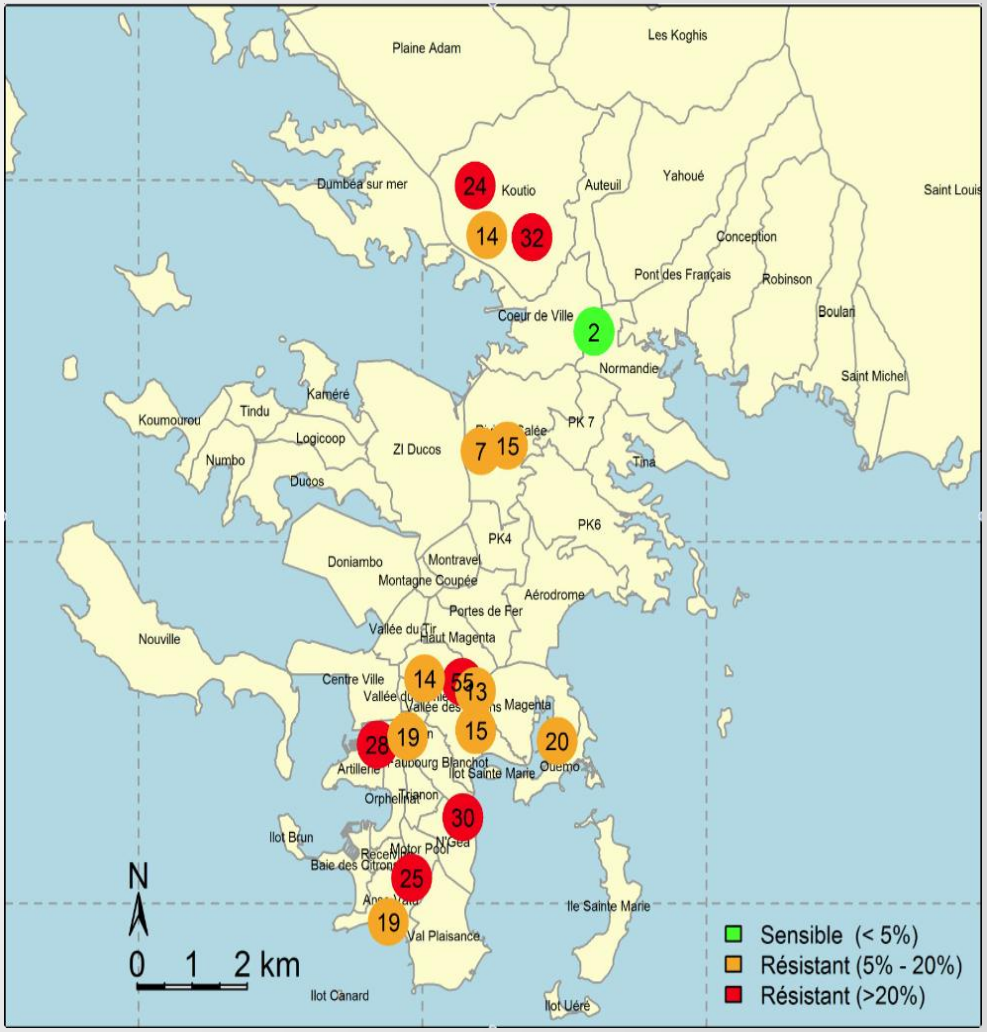
Spatial and temporal distribution of *Ae. aegypti* resistance to deltamethrin in Noumea

2013



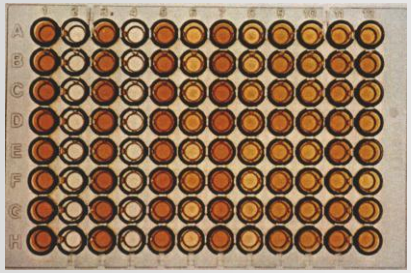
Resistance to deltamethrin in Noumea

Population	% resistance
Nouméa Normandie	2
Nouméa Centre Ville	28
Nouméa N'Géa	30
Nouméa Ste Marie	15
Nouméa Vallée des Colons A	55
Dumbéa Koutio 1	24
Nouméa Ouémo	20
Nouméa Motor Pool	25
Nouméa Vallée des Colons B	14
Dumbéa Koutio 2	14
Nouméa Anse Vata	19
Nouméa Rivière Salée A	7
Dumbéa Koutio 3	32
Magenta	13
Nouméa Rivière Salée B	15
Nouméa Quartier Latin	19

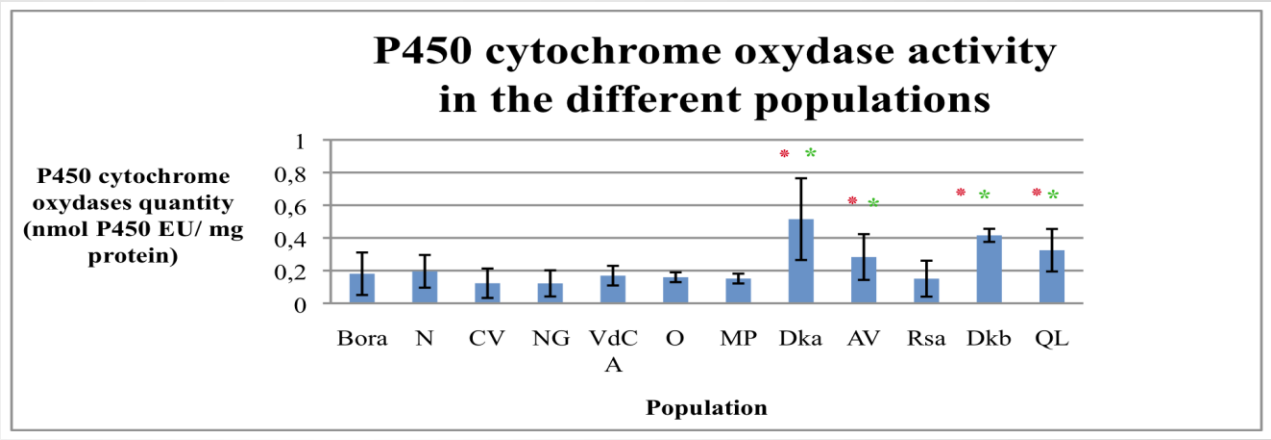


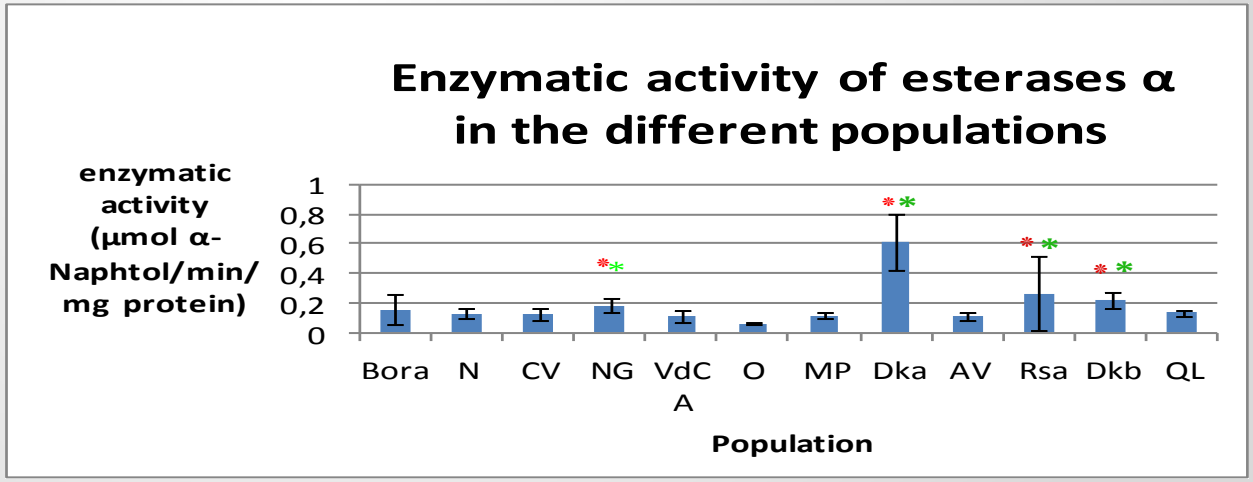
% resistance : <5% | 5%< <20% | >20%

Metabolic resistance : enzyme activities



Significant increase in enzyme activity observed in some populations





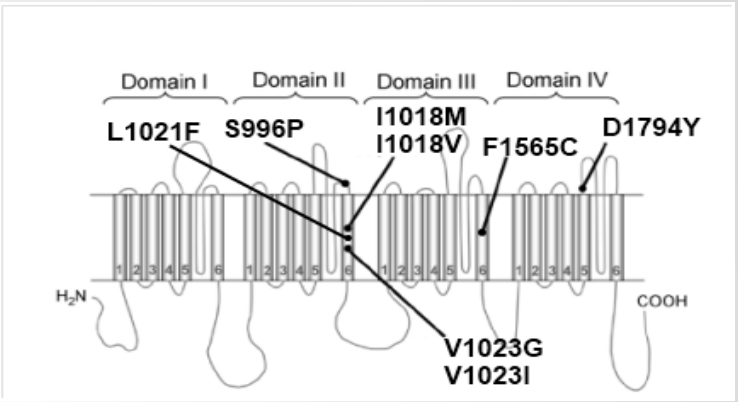
Molecular resistance : kdr mutations

Insecticide target : Voltage-gated sodium channel protein

➡ ***Kdr* mutations :**

Linked to pyrethroid resistance

Voltage-gated sodium channel protein : α sub-unit



(Kasai S. et al., 2011)

4 mutations in domains II and III	Occurrence In sampled populations	Functional properties
Mut1	67/102	Reduction of channel sensitivity to Permethrin and Deltamethrin
Mut2	15/102	Not known
Mut3	2/102	Not known
Mut4	5/102	Reduction of sensitivity only to Permethrin

Conclusions

➡ **Different resistance mechanisms :**

Detoxification enzymes and Kdr mutations

➡ Zones that were **highly treated by insecticides** showed **elevated detoxification enzyme activities and/or high kdr mutations**; especially those sprayed with deltamethrin.

Impact of households insecticides, especially in the South.

➡ Relatively low resistance levels (22% on average) were observed in NC in comparison with Martinique : 80% (Marcombe S. et al., 2009)

➡ Widespread and diverse resistance mechanisms reduce the capacity of management of resistance.

Threat for susceptibility to organophosphates.

Alternatives to control vector populations

- **Testing of biodegradable lethal ovitraps for *Ae. aegypti***
  (SIPRES - Ville de Nouméa, IPNC)

- **Potential use of Pyriproxyfen for control of *Ae. aegypti* in urban areas : the « auto-dissemination » approach**
  (DASS-NC, IPNC)

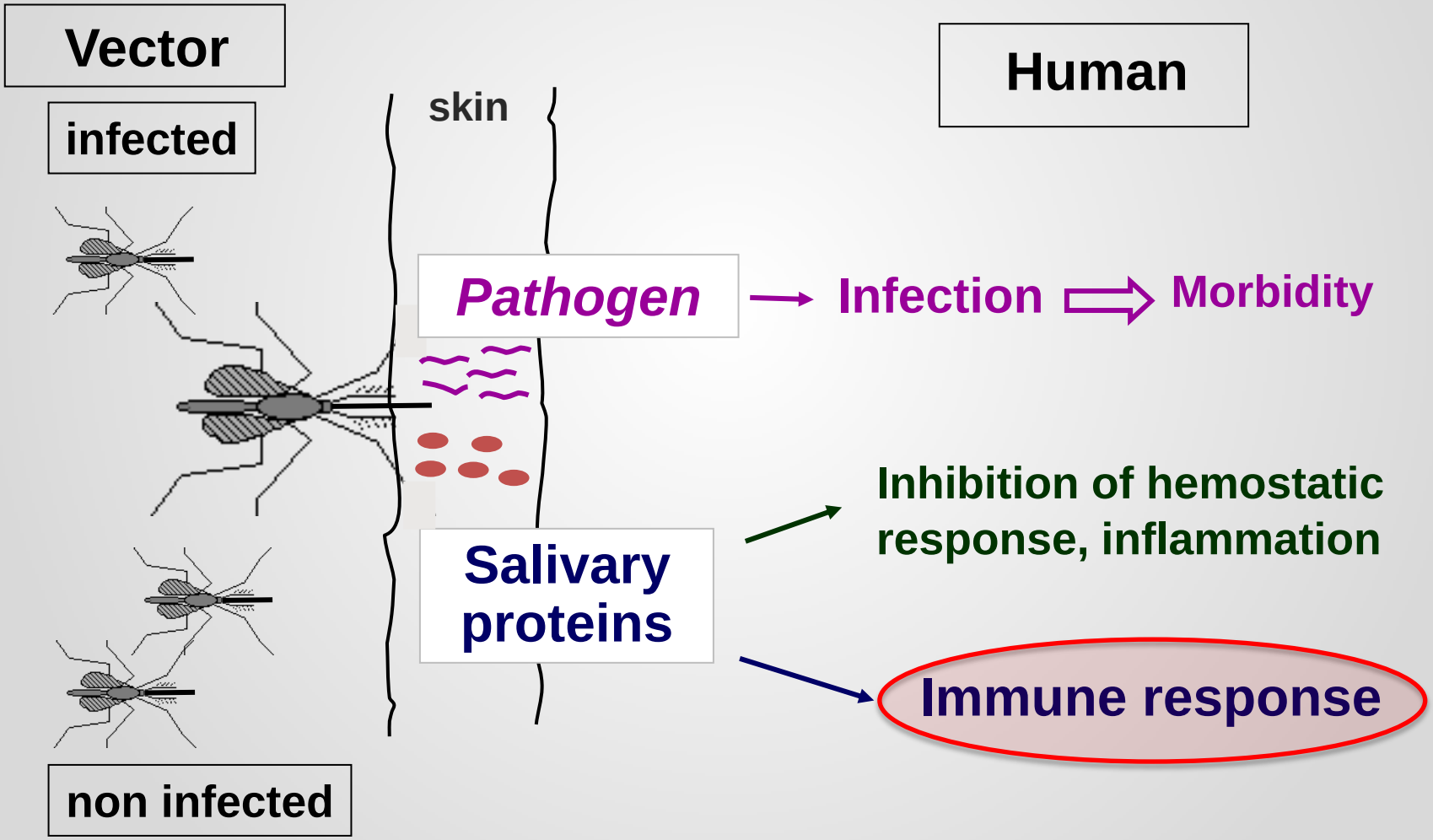
- **Promising tool : Incompatible Insect Techniques (IIT): *Wolbachia* and female sterilisation**

  BUT there is need for a tool to evaluate the efficacy of vector control strategies

  ⇒ **Biomarkers of exposure to mosquitoes**

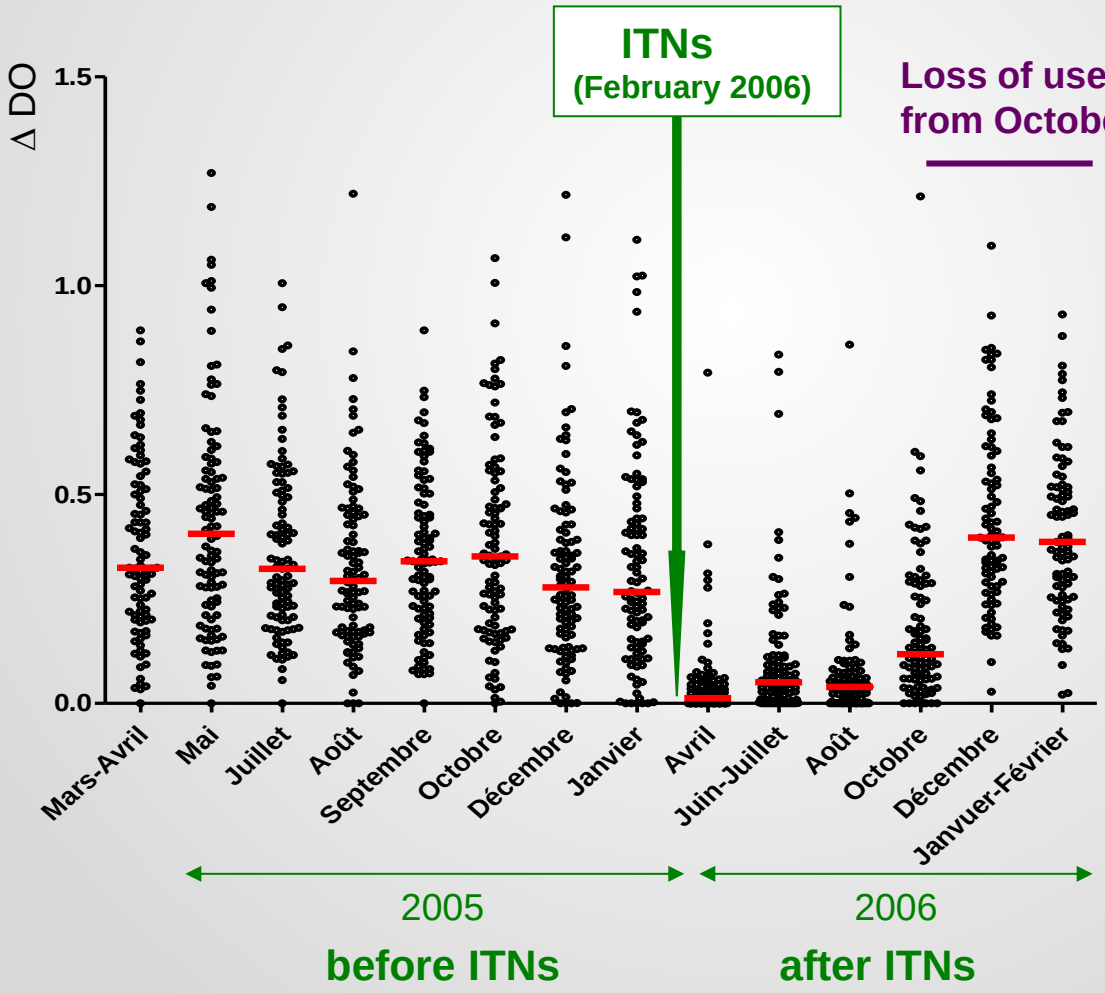
Biomarker of exposure to *Aedes* mosquitoes

Human - vector interaction



Biomarker of exposure to *Anopheles* mosquitoes

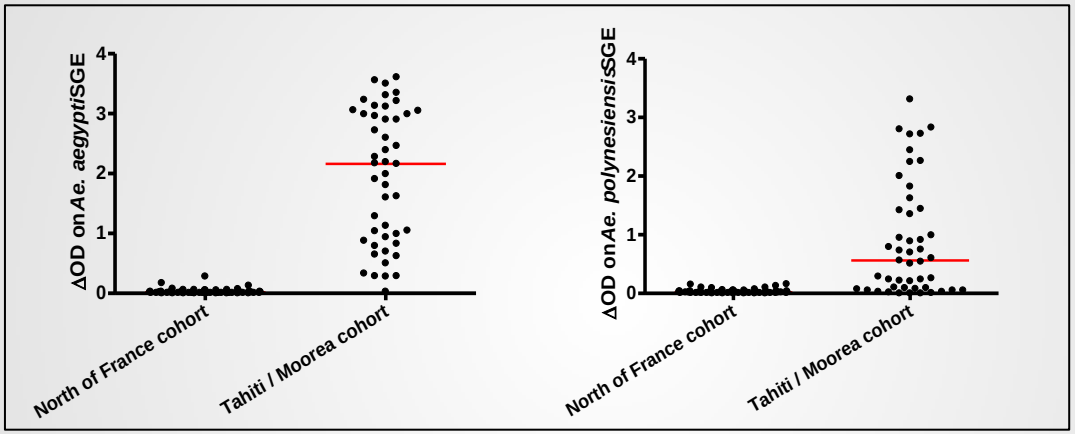
Human antibody responses to the *Anopheles* salivary gSG6-P1 peptide : a novel tool for evaluating the efficacy of ITNs in malaria vector control



Drame PM et al., PLOS One 2010

Biomarker of exposure to *Aedes* mosquitoes

Antibody response to *Ae. aegypti* and *Ae. polynesiensis* saliva in human populations from french Polynesia



Claverie A. et al., (2014)

Towards the identification of specific markers for *Ae. aegypti versus Ae. polynesiensis* exposure

Collaboration: Institut Louis Malardé, Tahiti
(Hervé Bossin, Aurore Claverie, Catherine Plichart)