Journées Scientifiques Annuelles d'Arbo-France

Moyens innovants de lutte contre les vecteurs d'arbovirus

23-24 juin 2025, Val de Grâce - Paris

Overview du contrôle de la transmission des arboviroses liées à Aedes

Historique et bilan du contrôle des Aedes

par Fabrice Chandre

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Historique et bilan de la lutte contre les Aedes

23-24 Juin 2025

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RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
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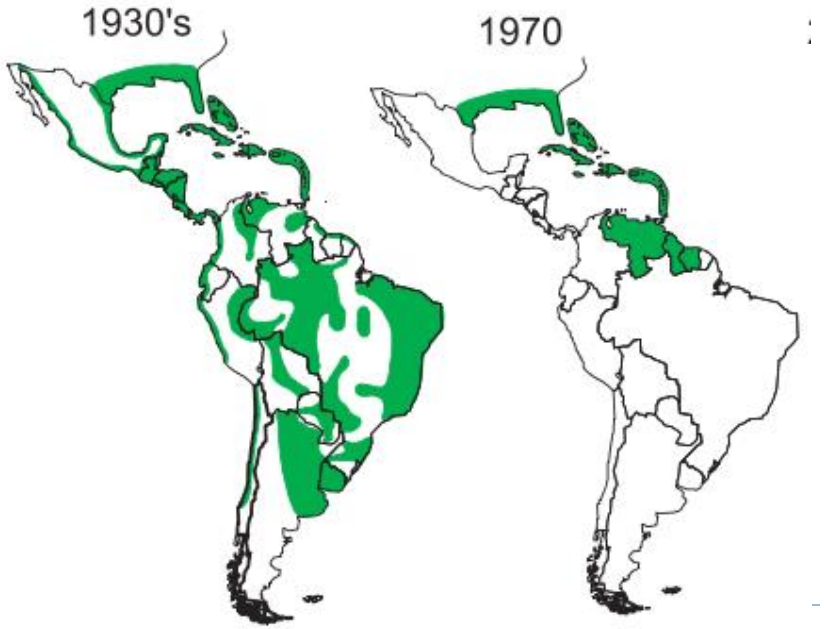
Succès historiques du contrôle d'Aedes aegypti

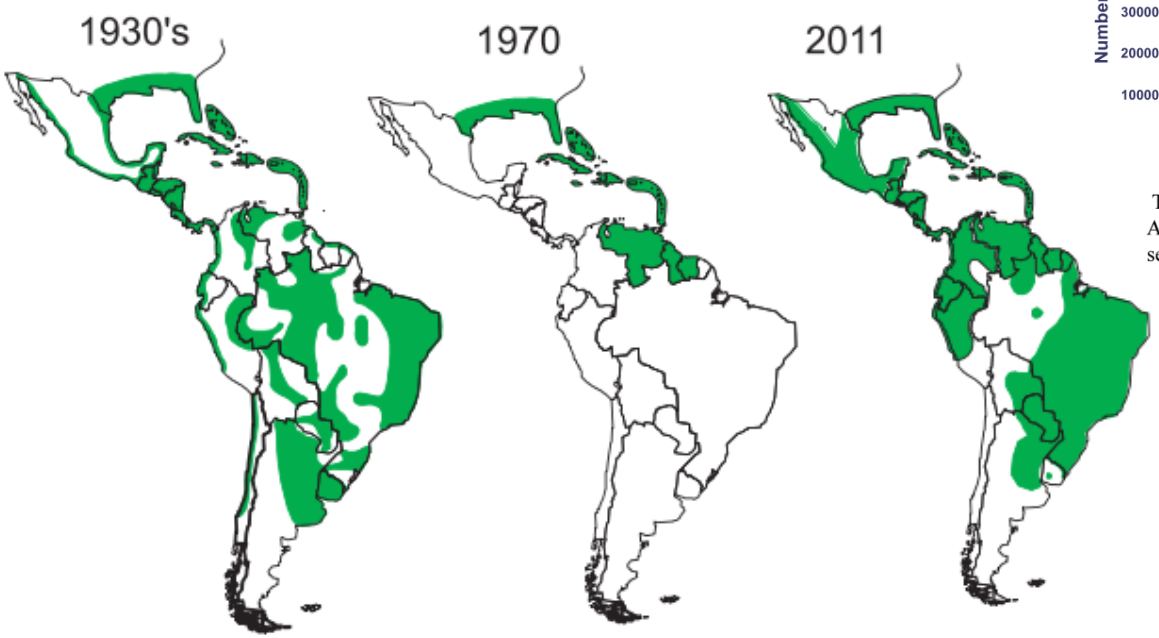
- Cuba (1901-1912), Canal de Panama (1904-1913), W. Gorgas: réduction de fièvre jaune par contrôle larvaire (élimination gîtes, huiles minérales) + isolement des malades, contraventions
- Brésil (1930-1942) F. Soper: réduction fièvre jaune et élimination partielle d'*Aedes aegypti*
- Am. Centrale, Am. Sud, Caraïbes (1946-1970) contrôle larvaire & traitement périfocal DDT- élimination d' d'*Aedes aegypti* dans 23 pays

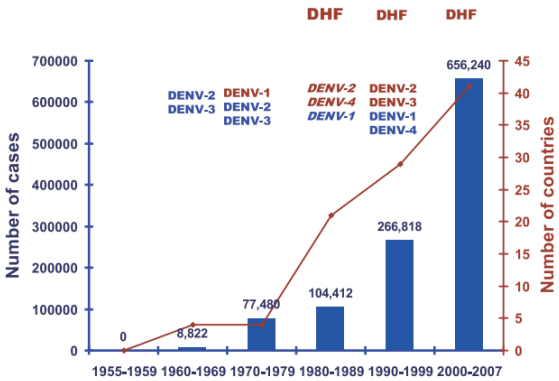


Gubler, TMH 2011

Recolonisation par *Aedes aegypti*

- Réduction des ressources pour le contrôle des vecteurs (Aedes, Anopheles) vers autres priorités de santé publique à partir de 1970
- Accroissement de la population, urbanisation non contrôlée, transport marchandises et personnes
- Résistance au DDT





The emergence of dengue hemorrhagic fever in the Americas associated with introduction of new virus serotypes and the development of hyperendemicity.

Gubler, TMH 2011

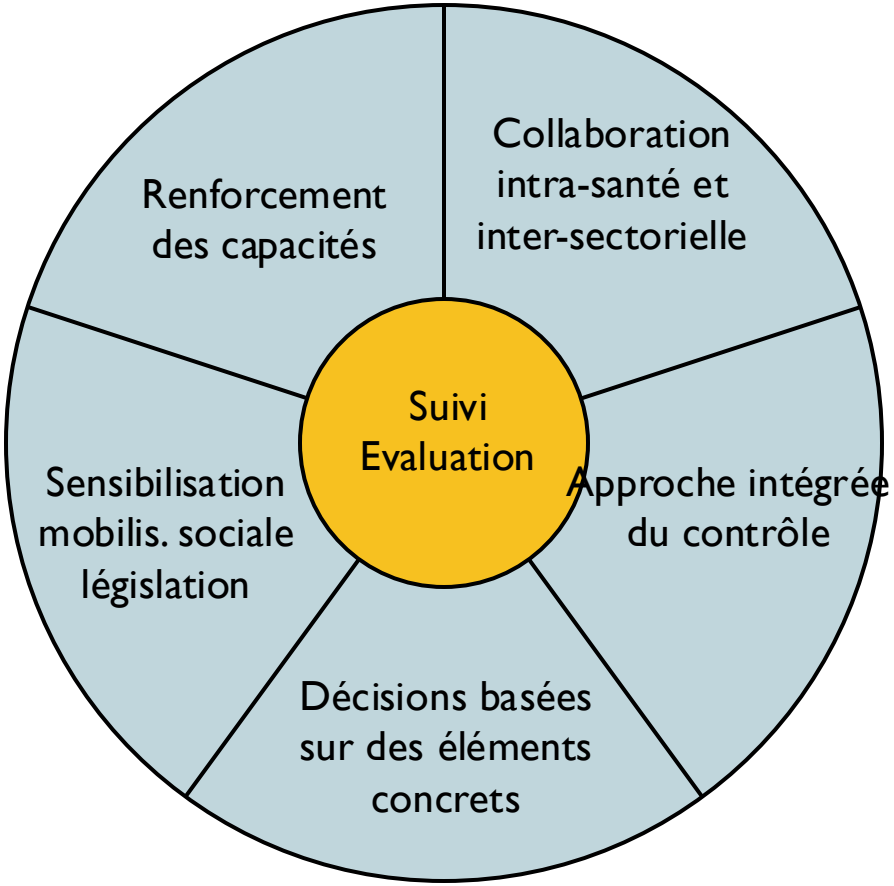
Gestion Intégrée des Vecteurs (OMS, 2004)

- processus rationnel de prise de décisions dans la perspective d'une utilisation optimale des ressources affectées au contrôle des vecteurs

Améliorer l'efficacité et l'efficience des interventions de contrôle des vecteurs

Réduire l'impact écologique et le recours aux insecticides

Réduire le nombre d'interventions en agissant sur plusieurs vecteurs et/ou plusieurs maladies vectorielles



Aedes aegypti et *Aedes albopictus*

- Très grande diversité des habitats larvaires
  - Gîtes domestiques

  - Gîtes péridomestiques

  - Gîtes naturels

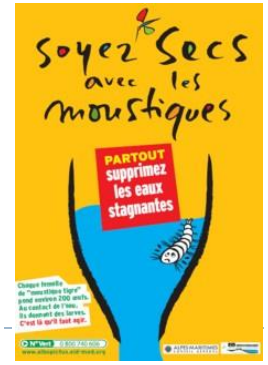
- Plasticité physiologique et écologique des *Aedes*
  - Anthropophile mais opportuniste (anx domestiques)
  - Diurne, pique au lever du jour et en fin d'après midi
  - La femelle pond qq œufs dans de nombreux gîtes
  - En l'absence de pluies les œufs résistent à la dessiccation
  - Diapause des œufs en hiver pour *A. albopictus*

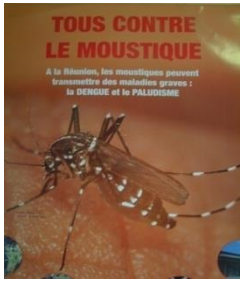
Lutte intégrée contre les *Aedes*

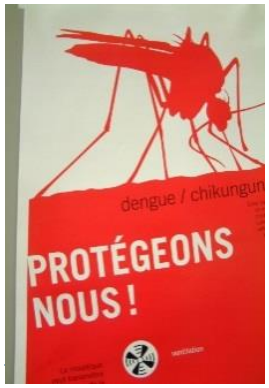
- Surveillance entomologique (indices larvaires, piégeage adultes)

- Protection réserves d'eau élimination petits gîtes

- Information, éducation sanitaire, mobilisation sociale







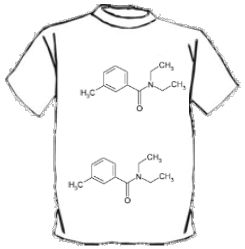
Lutte intégrée contre les *Aedes*

- Lutte larvicide: chimique, biologique

Mesocyclops ruttneri
M. aspericornis
M. thermocyclopoides
M. affinis
M. woutersi
M. ogunnus

- Lutte adulticide: thermonébulisation ou ULV en cas de circulation virale

- Protection personnelle: vêtements longs, imprégnés, répulsifs, moustiquaires



Insecticides en lutte antivectorielle

- Principales familles d'insecticides utilisées en LAV

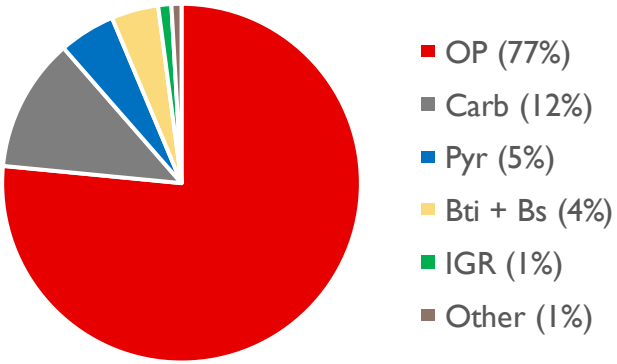
- Pyréthrinoïdes (et DDT Organochloré)
  - Inhibiteurs du Canal Sodium Voltage dépendant
  - Action rapide (knockdown), effet irritant, adulticides

- Organophosphorés et Carbamates
  - Inhibiteurs de l'acétylcholinestérase, adult-/larvicides

94% agissent sur 2 cibles !

- Régulateurs de croissance
  - Analogues hormonaux, perturbation du développement, larvicides

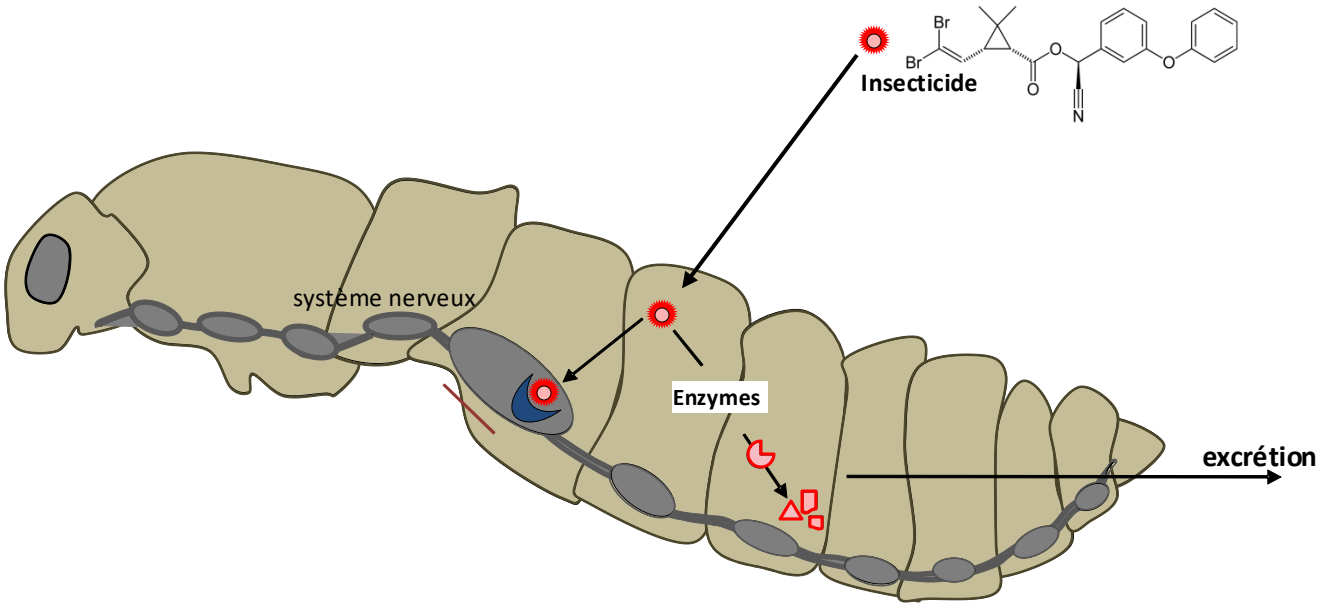
- Insecticides d'origine bactérienne *(Bti, Bs)*
  - Toxique/ingestion, épithélium intestinal, larvicides



% tonnage annuel 2010-2019 pour le contrôle des vecteurs d'arbovirus

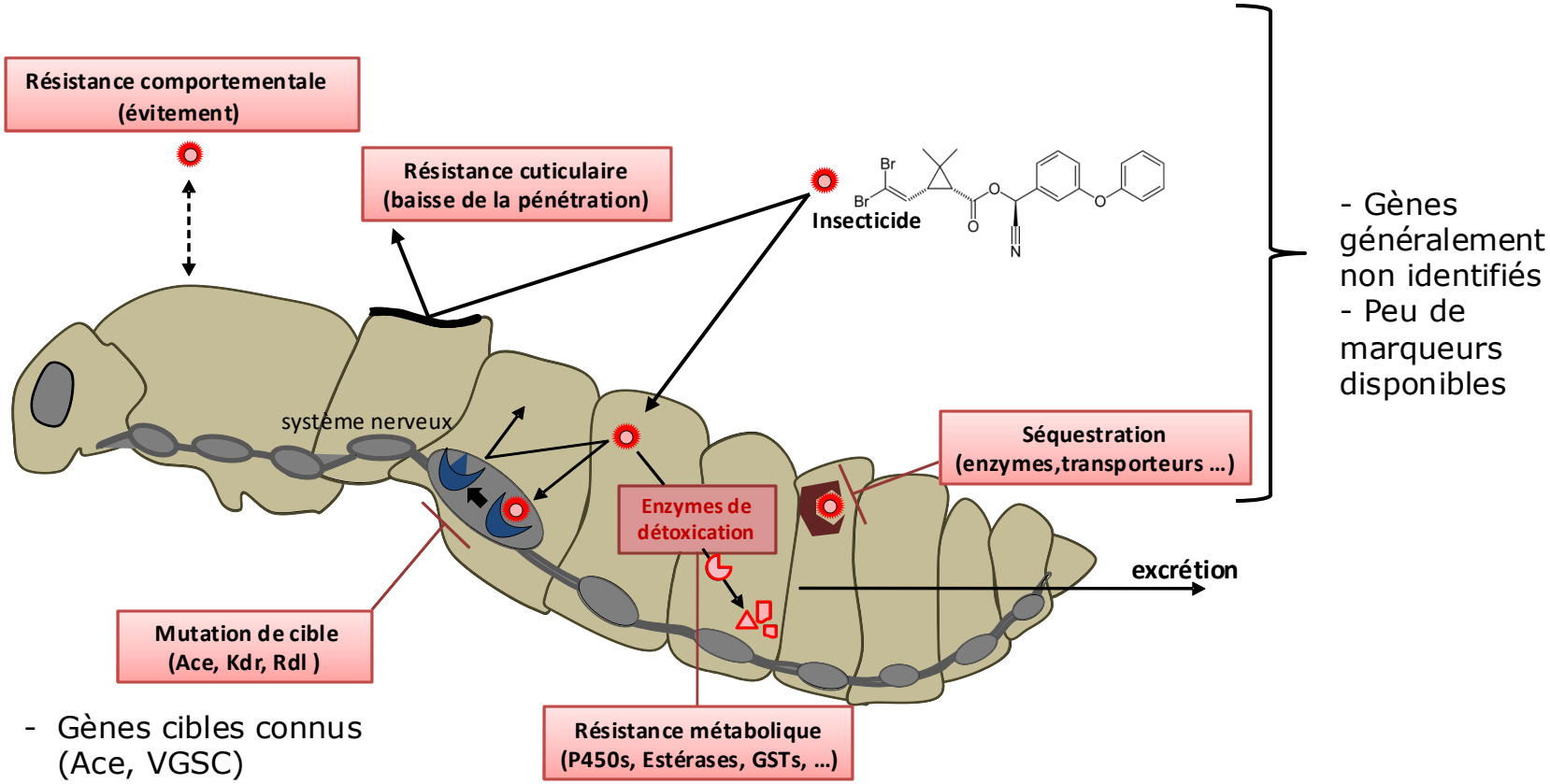
WHO, 2021 Global Insecticide Use for Vector-Borne Disease Control, 6th Ed.

Principaux mécanismes de résistance



D'après David et al. 2013, Phil. Trans. R. Soc. B

Principaux mécanismes de résistance



- Gènes cibles connus (Ace, VGSC)
- Mutations identifiées
- Marqueurs disponibles

- Très nombreux gènes (Cyto. P450, estérases, GST)
- Partiellement identifiés
- Peu de marqueurs, expression (ARNm, protéines) ou CNV

D'après David et al. 2013, Phil. Trans. R. Soc. B

Résistance d'*Aedes aegypti* à la deltaméthrine (adulticide) *(Moyes et al., 2017, Plos NTD)*

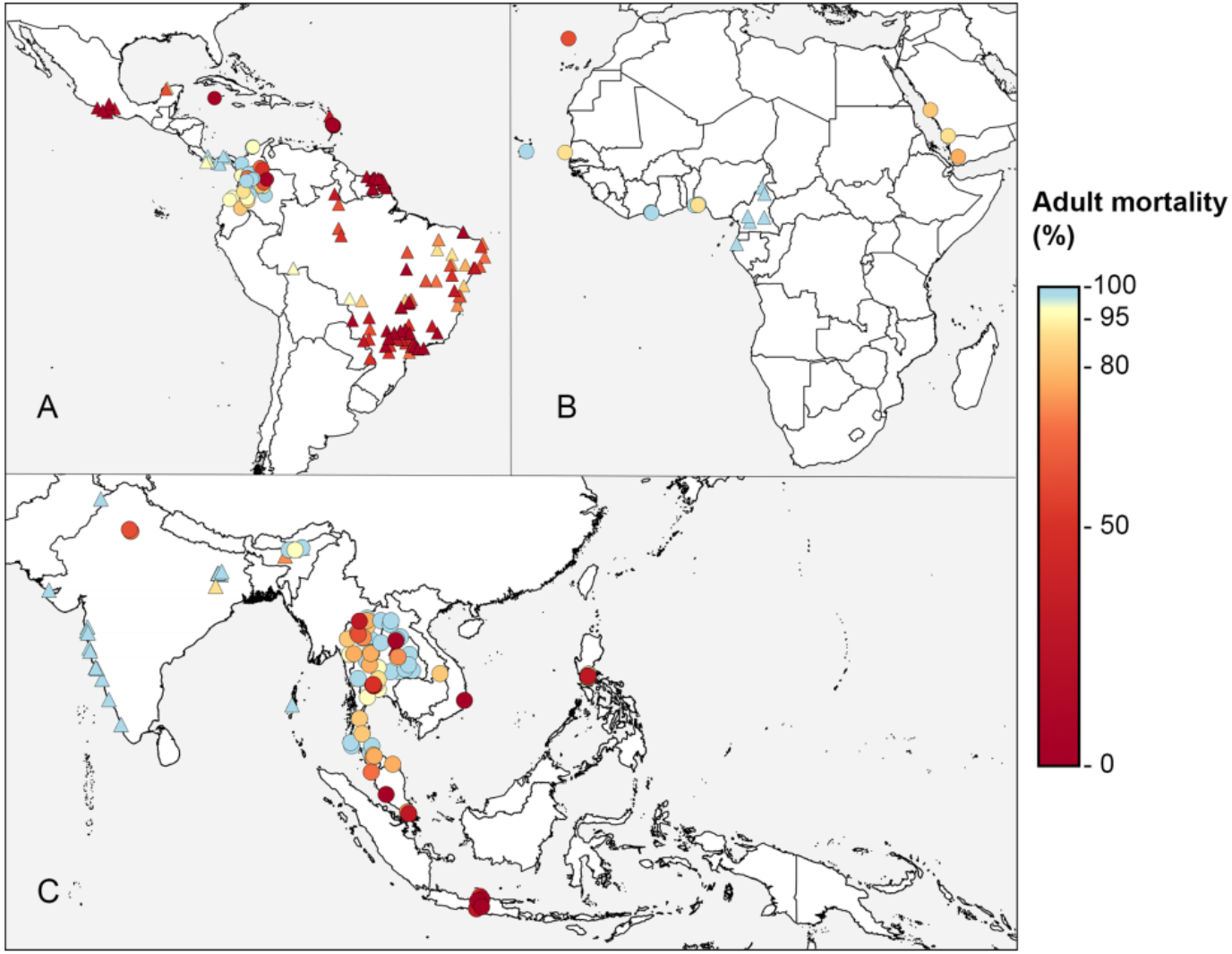


Fig 2. The frequency of resistance to deltamethrin in *Ae. Aegypti*, 2006–2015. Adult bioassays using 0.05% insecticide for 1 hour are denoted as circles and results from nonstandard adult bioassays (including different diagnostic doses and exposure periods) are denoted as triangles. The map is zoomed to the 3 regions with data. **(A)** Americas. **(B)** Africa/Arabian Peninsula. **(C)** Asia.

Résistance d'*Aedes aegypti* au téméphos (larvicide) *(Moyes et al., 2017, Plos NTD)*

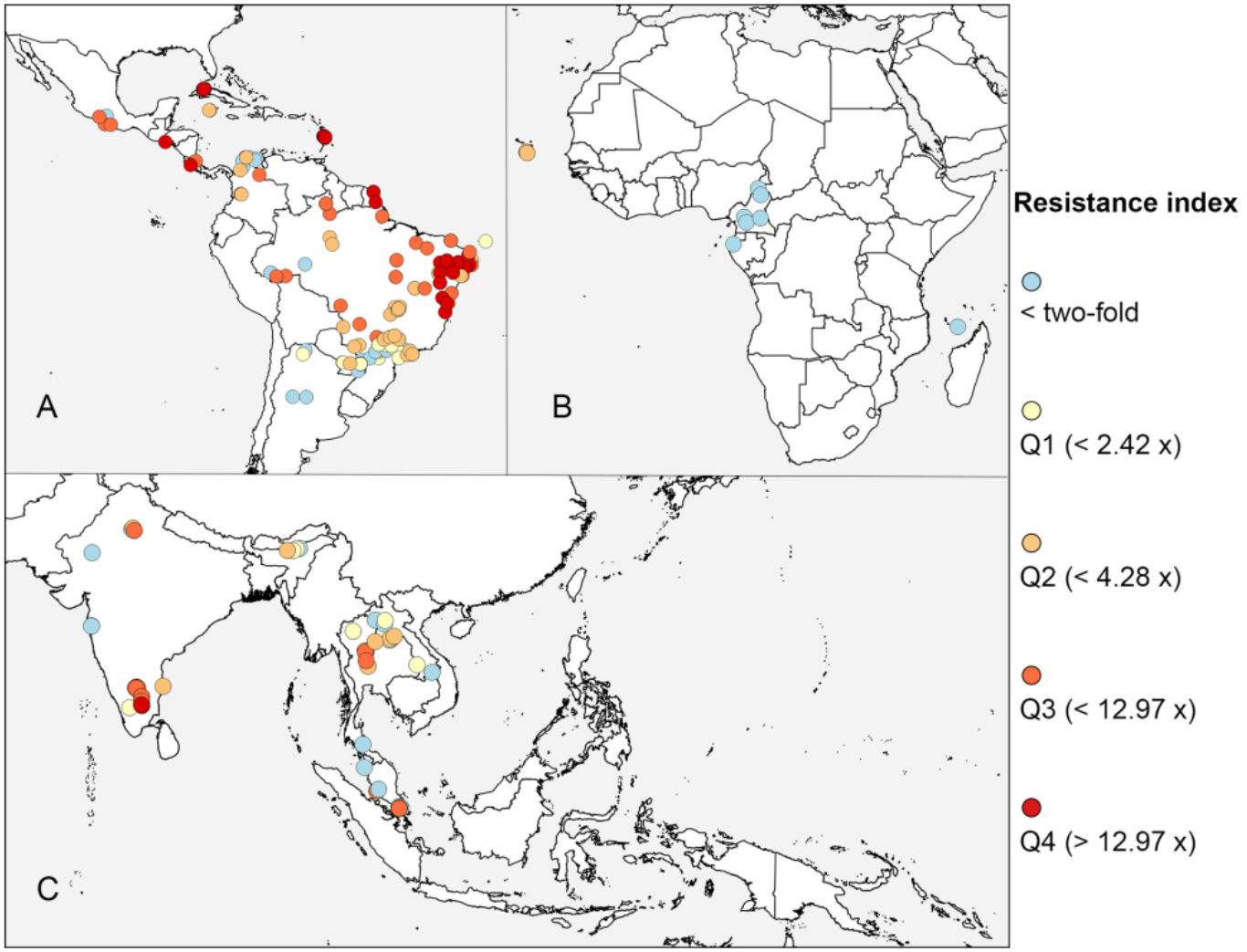
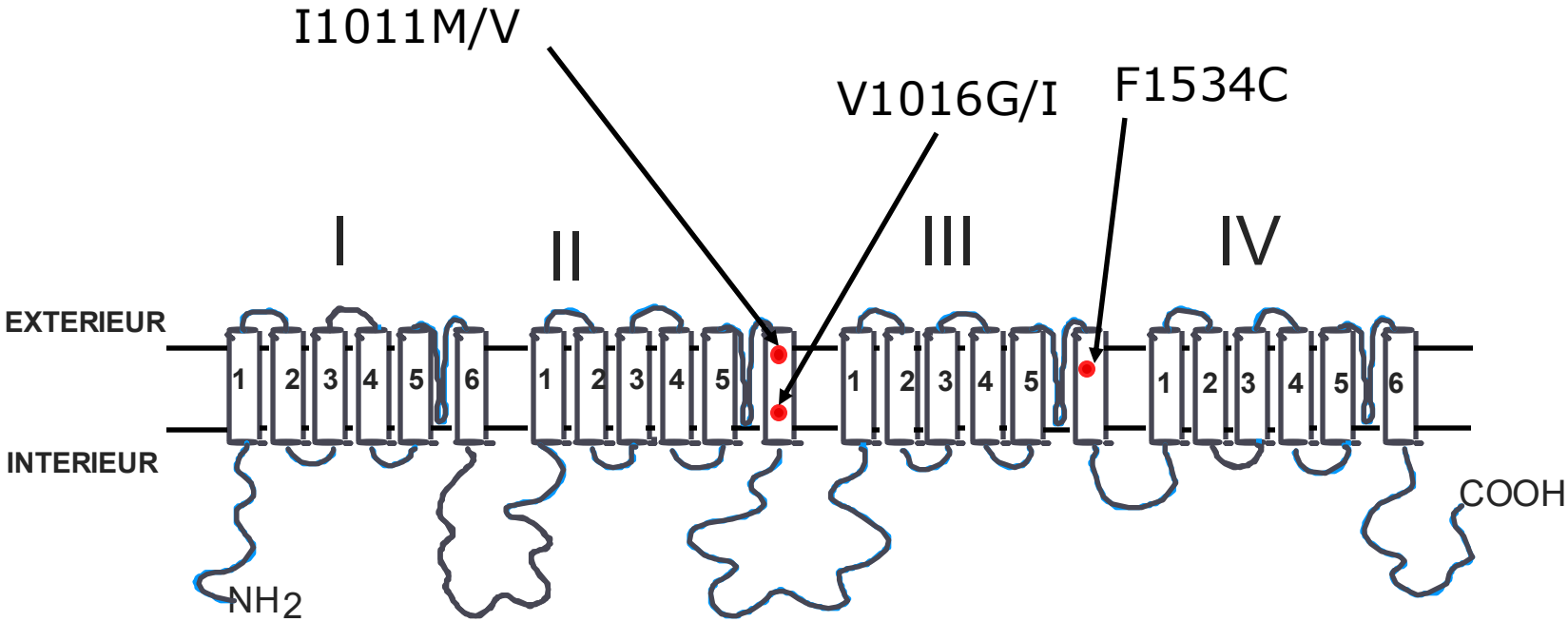


Fig 3. The level of *Ae. aegypti* resistance to temephos, 2006–2015. The ratio of the lethal concentration required to kill half of the sample (LC_{50} value) obtained by each study to the value obtained for the Rockefeller susceptible strain across studies was calculated. The ratios were then split into 5 classes: values less than 2-fold higher than Rockefeller and each quartile of the remaining distribution. The map is zoomed to the 3 regions with data. **(A)** Americas. **(B)** Africa. **(C)** Asia.

Canal sodium et mutations *kdr* chez *Aedes aegypti*



Moyes et al. 2017
Plos NTD

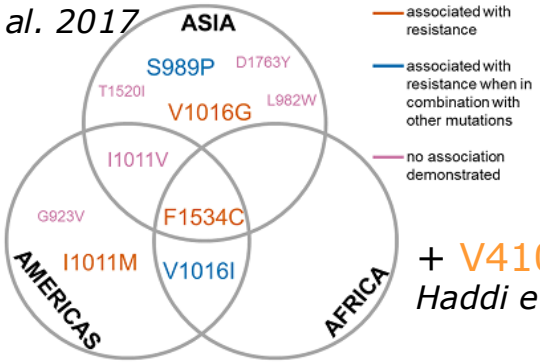


Fig 5. The geographical distribution of the 10 known voltage-gated sodium channel (VGSC) mutations in *Aedes aegypti* across the 3 continents in which they have been detected. Association of each mutation with pyrethroid resistance is shown in the key. Font size gives an indication of relative frequency.

+ V410L
Haddi et al. 2017

V1016G, F1534C aussi présentes chez *Ae. albopictus*

Enzymes impliquées dans la résistance métabolique (validation fonctionnelle) – Anses 2021

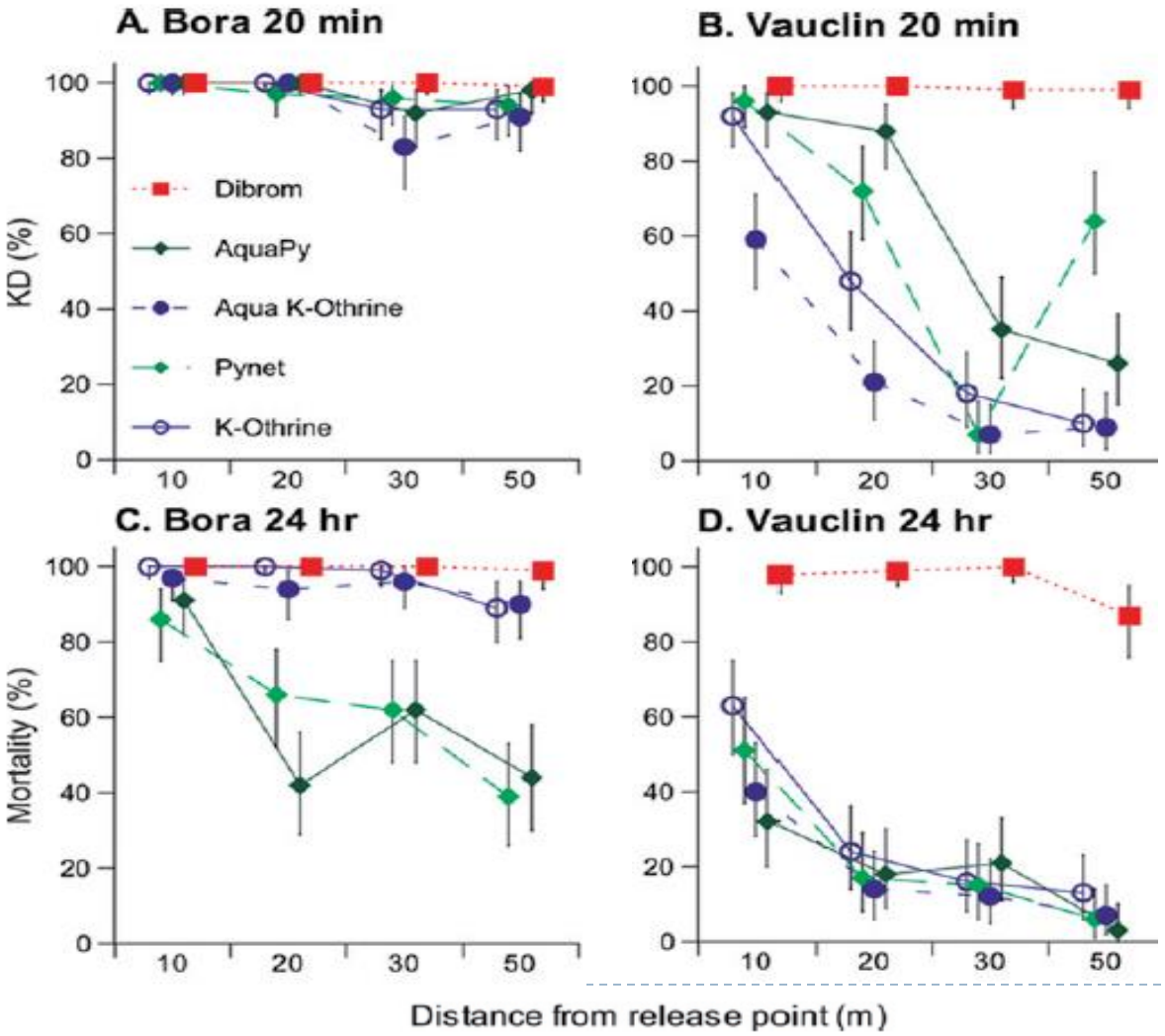
Tableau 10. Principaux marqueurs moléculaires utilisables pour détecter la résistance métabolique

Espèce	Gène[1]	Famille Enzymatique	Insecticides	CNV détecté[2]	Références
Ae. aegypti	CYP9J32	P450	PYR	oui	Stevenson *et al.* 2012, Kasai *et al.* 2014, Faucon *et al.* 2015, Smith *et al.* 2016*, Moyes *et al.* 2017*, Faucon *et al.* 2017, Cattel *et al.* 2020a, Cattel *et al.* 2020b
	CYP9J26	P450	PYR	oui	
	CYP9J28	P450	PYR	oui	
	CYP9J24	P450	PYR	oui	
	CYP9M6	P450	PYR	oui	
	CYP6BB2	P450	PYR	oui	
	CCEAE3A	COE	OP	oui	
	GSTE2	GST	PYR, DDT	oui	
Ae. albopictus	CYP6P12	P450	PYR	non	Grigoraki *et al.* 2015
	CCEAE3A	COE	OP	oui	Ishak *et al.* 2016
Cx. pipiens / quinquefasciatus	CYP9M10	P450	PYR	oui	Weill *et al.* 2000 Hardstone *et al.* 2010, Scott *et al.* 2015*, Gong *et al.* 2017,
	CYP6AA7	P450	PYR	non	
	CYP4H24	P450	PYR	non	
	CPIJ013917 (Est2)	COE	OP	oui	
	CPIJ013918 (Est3)	COE	OP	oui	

[1] Seules les enzymes dont la capacité à dégrader les insecticides a été validée sont indiquées.

[2] Variations du nombre de copies (CNV) détectées dans les populations naturelles (résistance éventuellement détectable sur ADN génomique). * articles de synthèse.

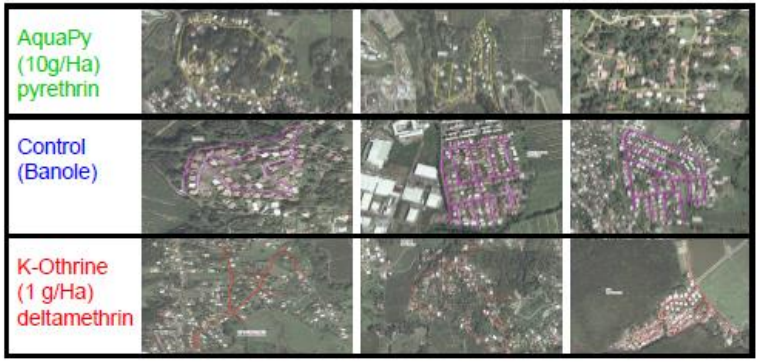
Impact des pulvérisations spatiales sur *Ae. aegypti* resistant à la deltaméthrine en Martinique (phase II)



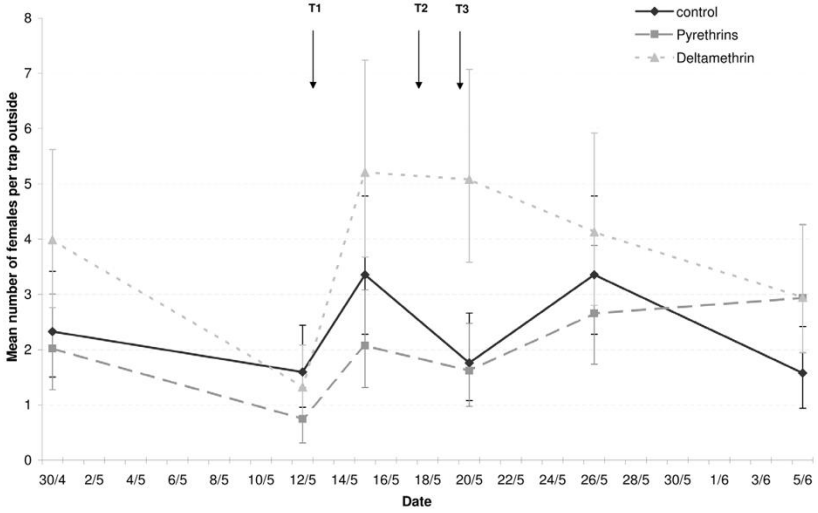
Marcombe et al., AJTMH 2008

Impact de la résistance sur l'efficacité opérationnelles des traitements en Martinique

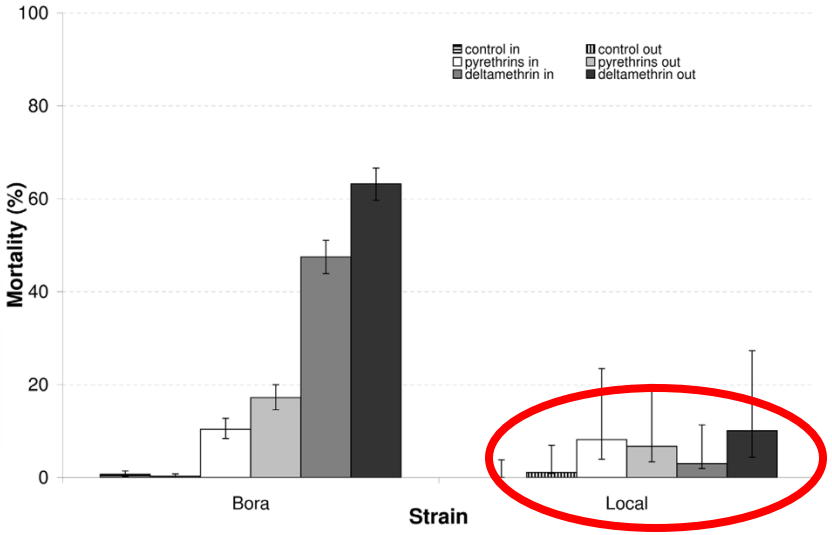
- **Treated arms**



- **3 rounds of space spraying , 1 every 3 days**



Femelles capturées par pièges BG ext. avant et après traitement



Mortalités relevées en cages sentinelles

Perte d'efficacité des traitements

- En conditions de terrain :
  - Perte totale d'efficacité des traitements ULV à la deltaméthrine sur *Aedes aegypti* à la Martinique

Marcombe et al., Plos NTD 2011

Impact épidémiologique de la résistance

Pas de preuve directe d'un impact épidémiologique de la résistance mais une relation résistance et incidence des cas est suspectée

Incidence microcéphalies attribuables au virus Zika (2016)

Cas de microcéphalies

Résistance temephos (OP)

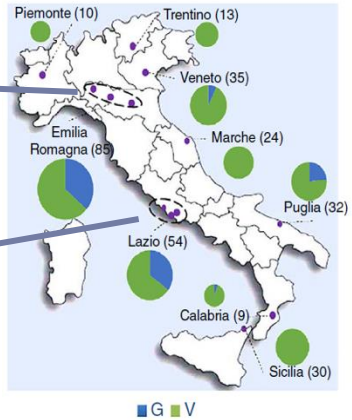
Incidence microcéphalies plus élevée dans les zones où *Ae. aegypti* est résistant au téméphos

Chediak et al., 2016

Incidence Chikungunya (2007 & 2017)

>200 cas autochtones en **Emilie Romagne** en 2007

~500 cas autochtones cases dans le **Latium** en 2017



Incidence chikungunya plus élevée dans les zones où *Ae. albopictus* est résistant aux pyréthrinoides

Pichler et al., 2019

Bilan et Conclusion

- M. Chan, Directrice Générale de l'OMS en 2016 (66th WHA)

"Above all, the spread of Zika, the resurgence of dengue, and the emerging threat from chikungunya are the price being paid for a massive policy failure that dropped the ball on mosquito control in the 1970s"

- Les campagnes préventives de contrôle des *Aedes* ont été peu à peu remplacées par des réponses d'urgence face aux épidémies

- Incertitudes sur l'efficacité des méthodes de lutte en fonction du contexte épidémiologique du fait de l'absence d'évaluation robuste

- Résistance aux insecticides

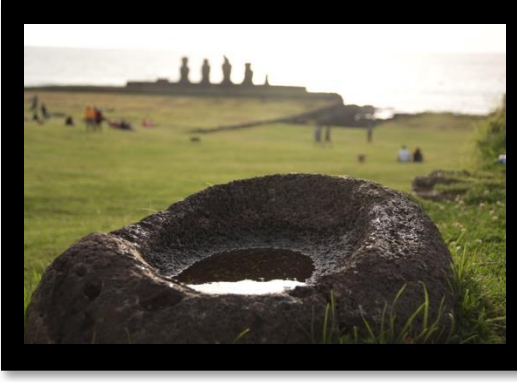
Bilan et Conclusion

- Nécessité de développer des méthodes alternatives, insecticides à nouveau mode d'action, outils non insecticides

- Vector Control Advisory Group (OMS) nouveaux outils doivent démontrer leur impact en terme de santé publique i.e. impact épidémiologique et entomologique via ERC
  - Répulsifs spatiaux (Pérou, Sri Lanka)
  - Piège Autodissémination (Laos, Cambodge, Malaisie)
  - Wolbachia IP (Indonésie, Brésil, Vietnam)
  - Wolbachia TII + TIS (Singapour)
  - TIS (Polynésie, non ERC)

Evaluation et Impacts des méthodes de contrôle

par David Roiz





Evaluation and impacts of vector control methods

David Roiz

MIVEGEC Unit. Institut de Recherche pour le Développement (IRD)

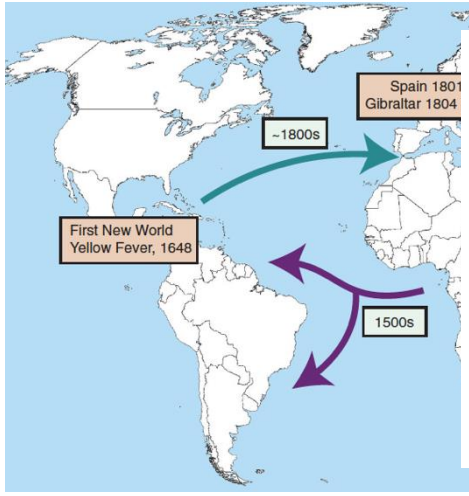
23-24 June 2025, ARBOFRANCE, Paris

Menu for today

1. *Aedes*-borne diseases: limitations on vector control
2. The Integrated *Aedes* Management (IAM) framework
3. Integrated Surveillance and integrated vector control
4. Evidence-based, what evidences we have for several control methods?
5. Pitfalls for evaluation and creating evidence-based decisions
6. Social mobilisation, intersectoral collaboration, additional activities
7. The rising global economic costs of *Aedes*-borne diseases
8. Multi-sectoral impacts
9. Prospects for the future and take-home messages

The spread of *Aedes* mosquitoes..

Aedes aegypti

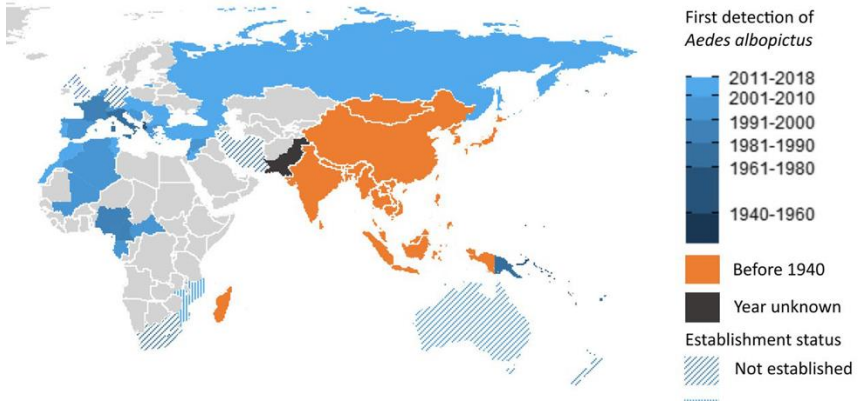


Vector control is the mainstay of the prevention

(in research for efficient vaccines)

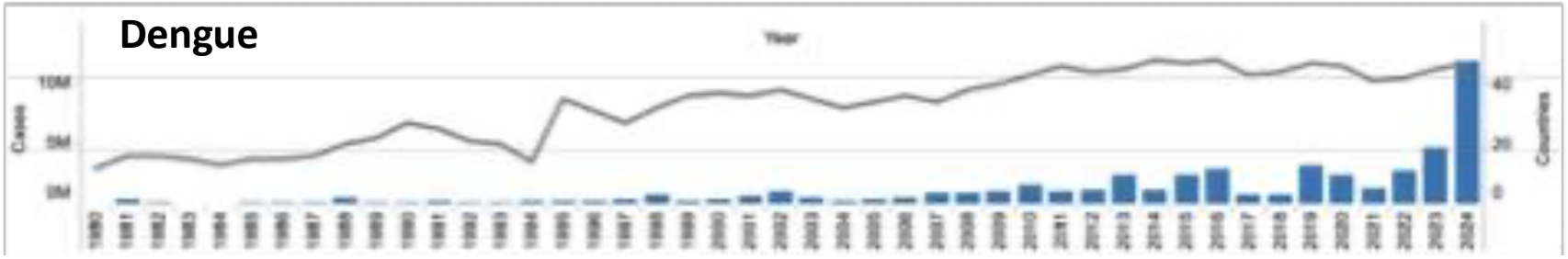
$$V_c = \frac{m a^2 b p^n}{-ln(p)}$$

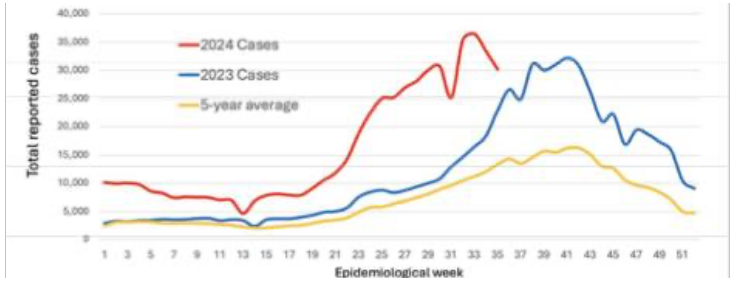
Aedes albopictus



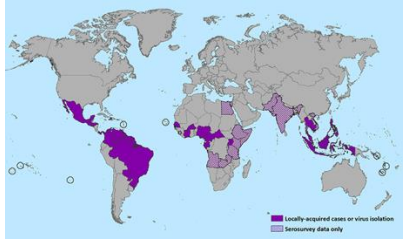
..cause a global health burden: *Aedes*-borne diseases

Dengue

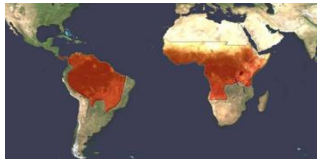




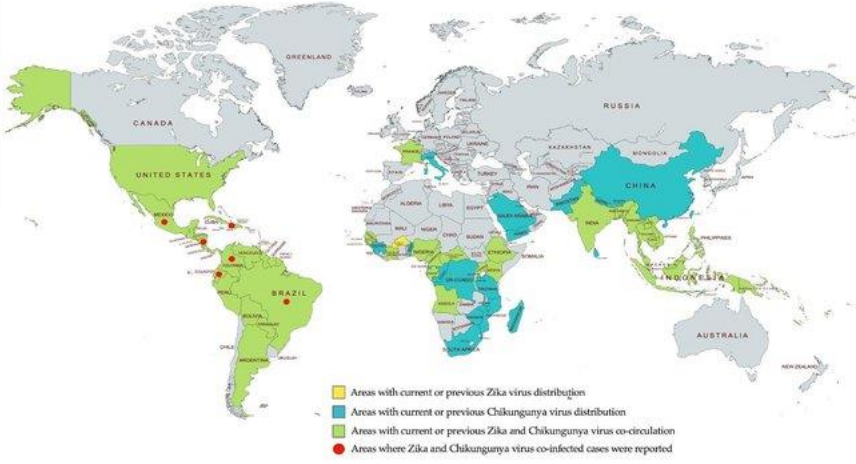
Zika



Yellow fever

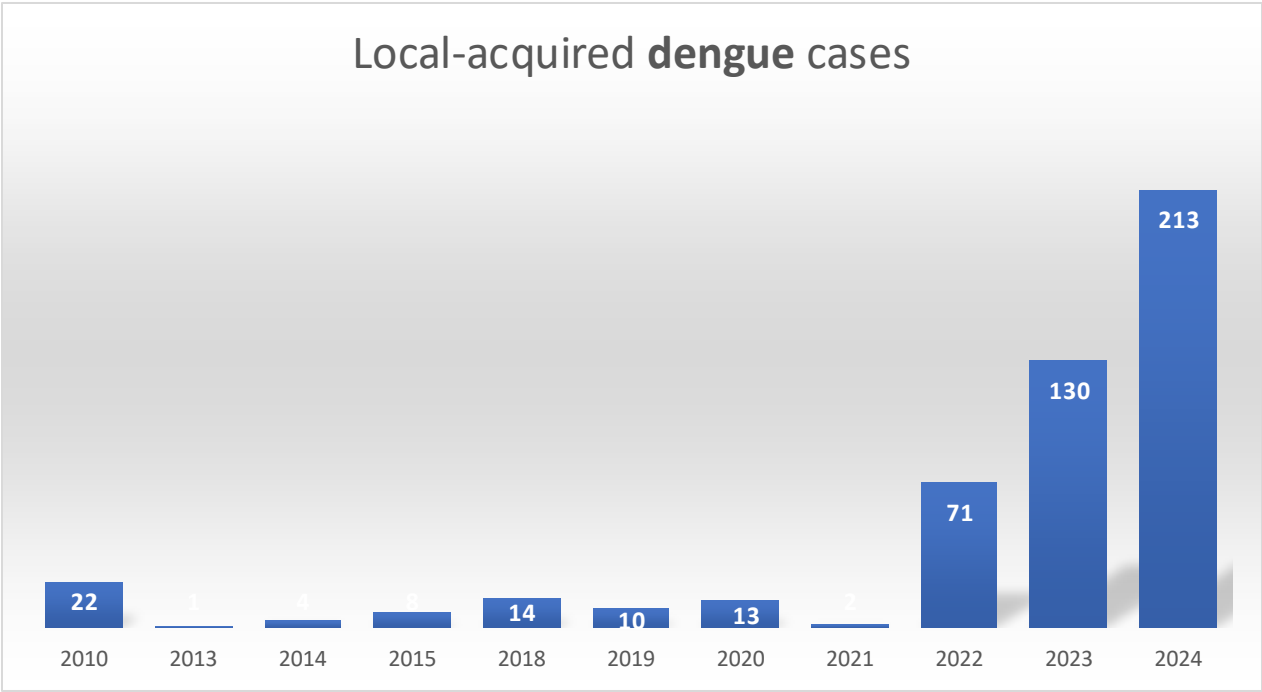


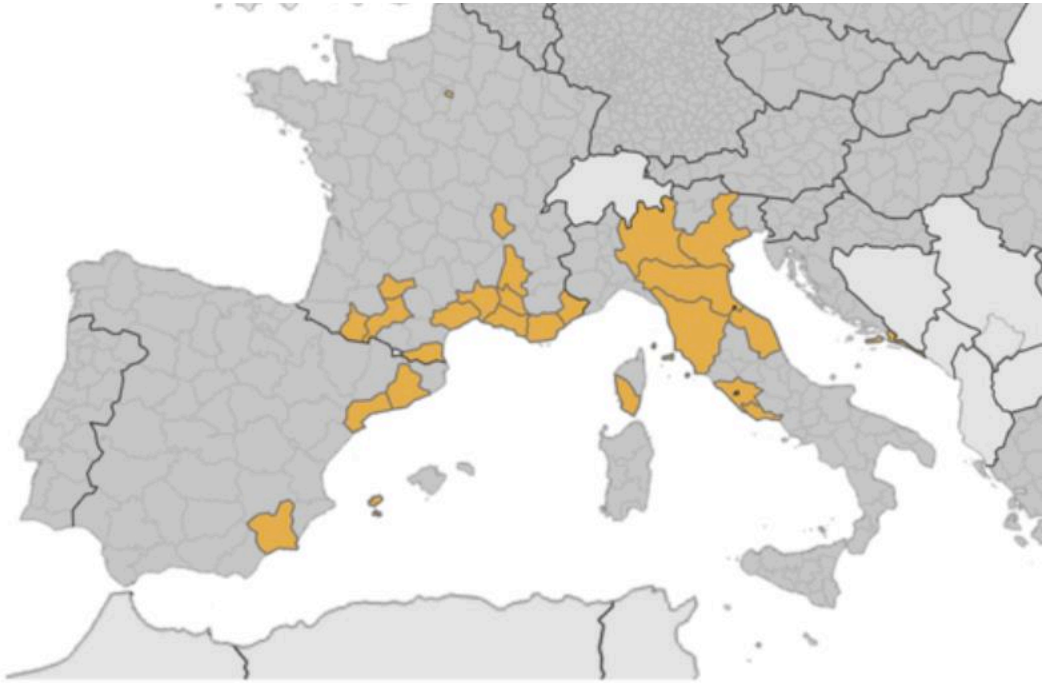
Chikungunya

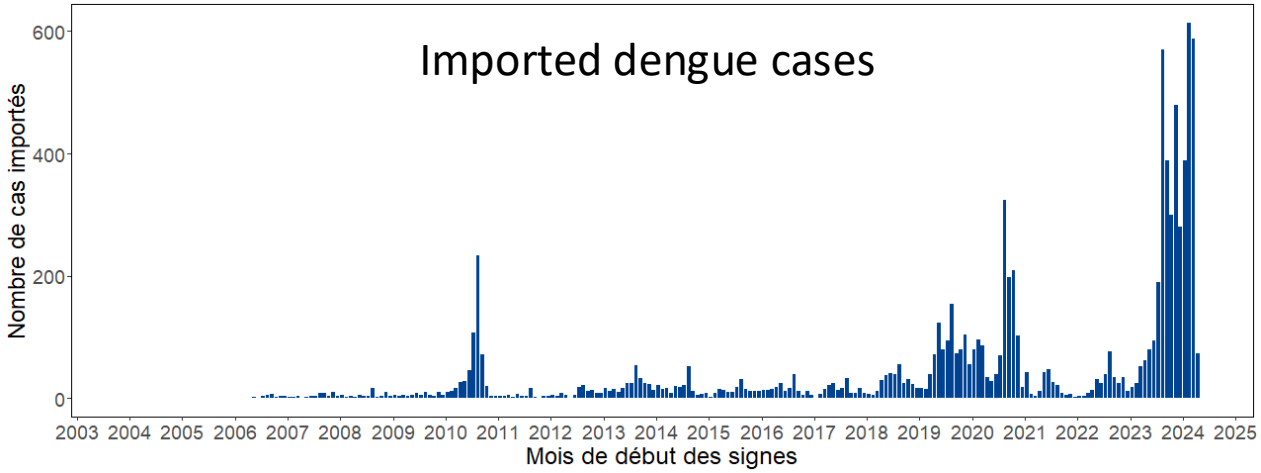


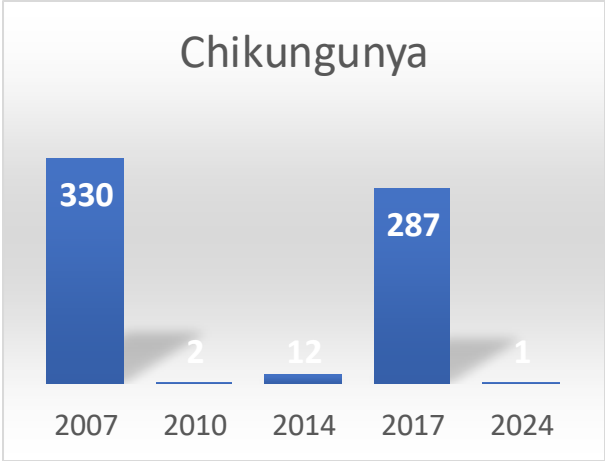
WHO, 2024; CDC; 2024; Wichit et al., 2021; Powell et al., 2018; Swan et al., 2022

Also in Europe…

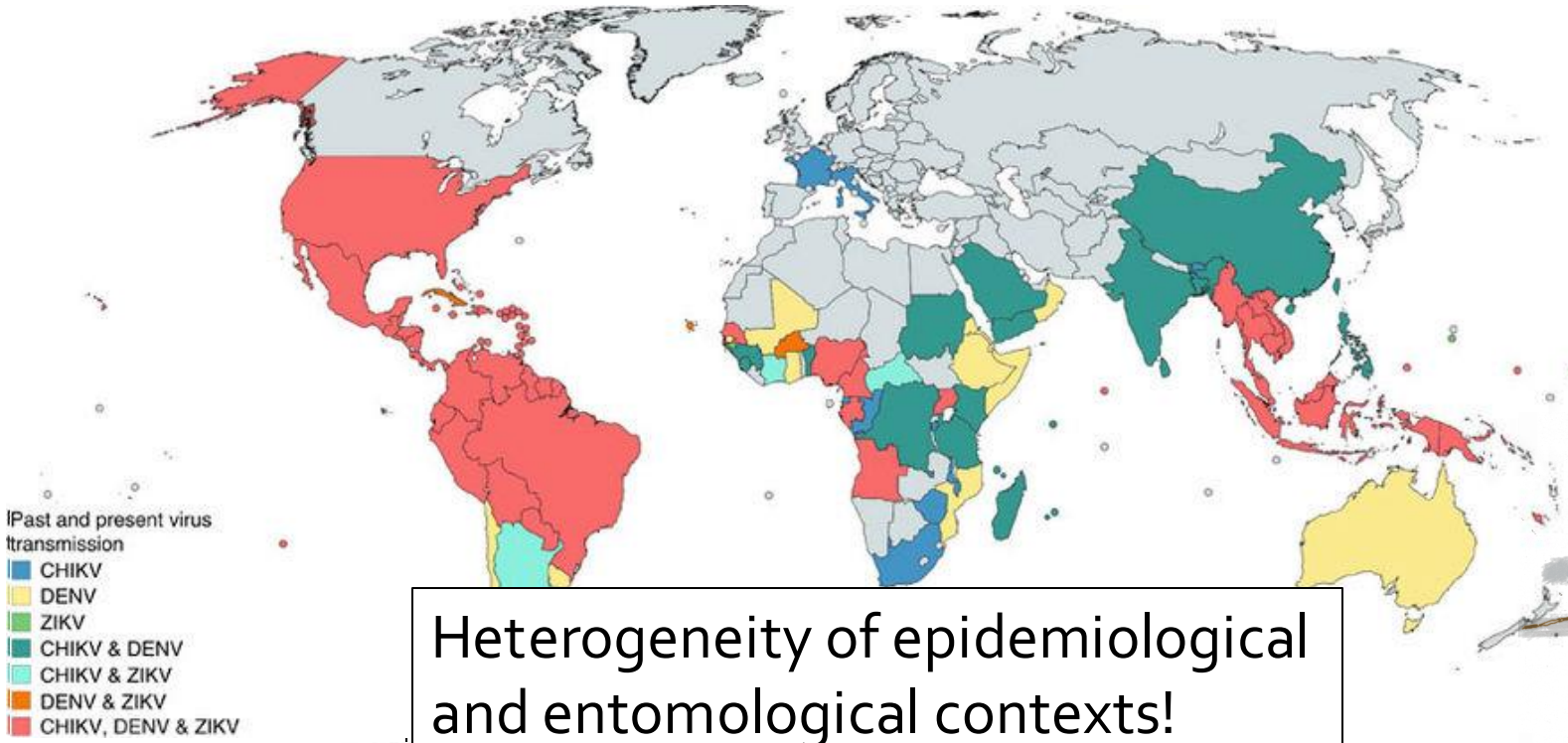




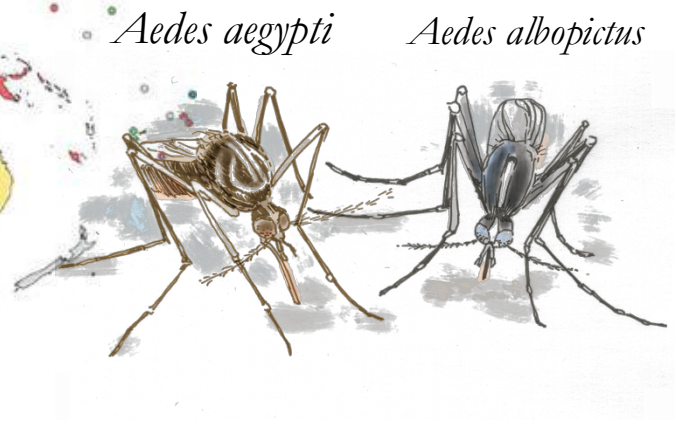




ECDC, SpF, 2024



Heterogeneity of epidemiological and entomological contexts!



Limitations of *Aedes* vector control

- Ineffective implementation (difficulties for top-down)
- Inadequate human, financial and infrastructural capacities in low-income
- Lack of community engagement
- Aversion to insecticiding and insecticide resistance
- Lack of political will

Weak evidence base for the effectiveness, costs, and public health value of *Aedes* vector control strategies

Background – Basis of the IAM framework

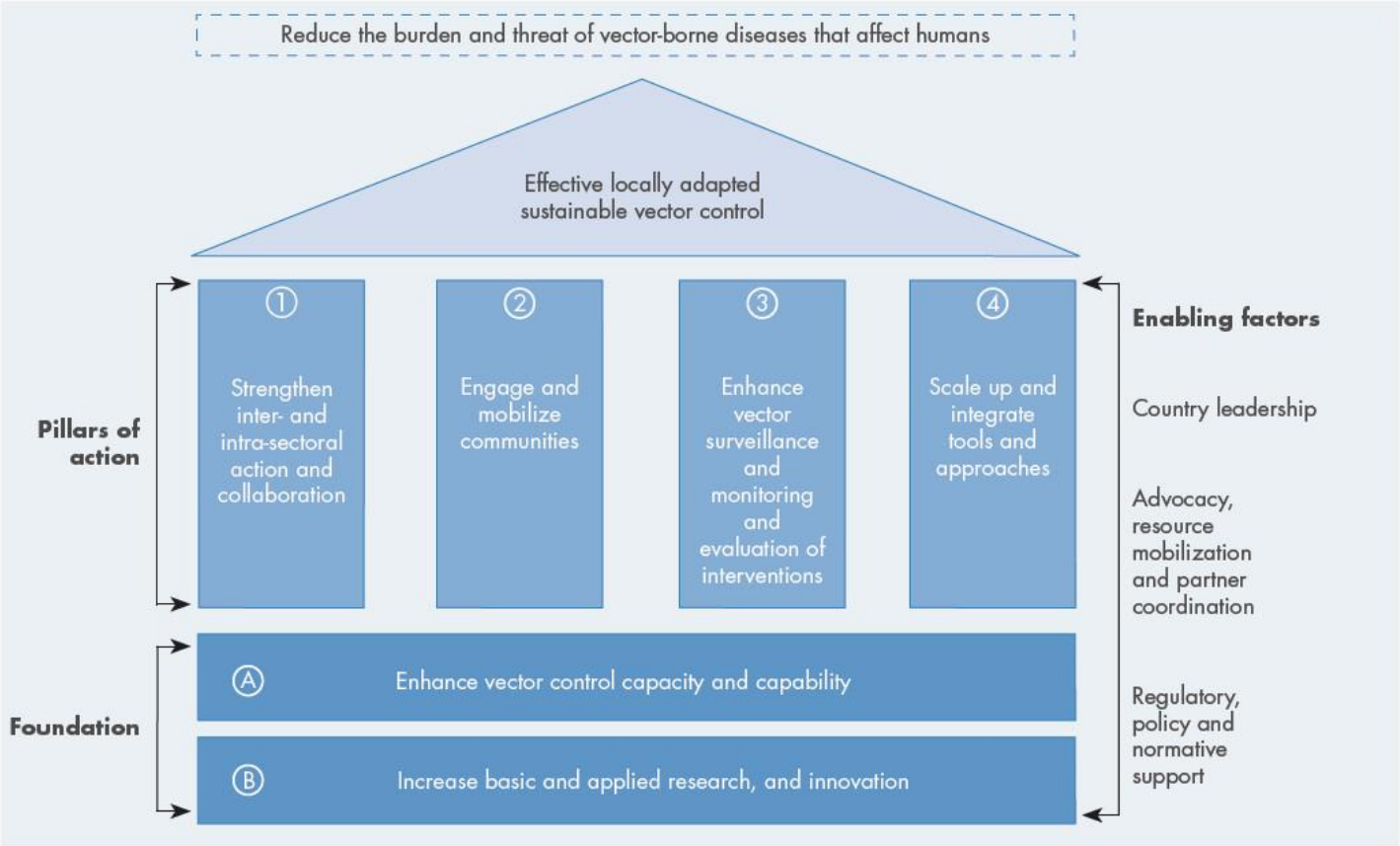
PLOS | NEGLECTED TROPICAL DISEASES

REVIEW

Integrated *Aedes* management for the control of *Aedes*-borne diseases

David Roiz[1]*, Anne L. Wilson[2], Thomas W. Scott[3], Dina M. Fonseca[4], Frédéric Jourdain[1], Pie Müller[5,6], Raman Velayudhan[7], Vincent Corbel[1]*

Locally-adapted practical guidance on how and when to deploy vector management in different settings

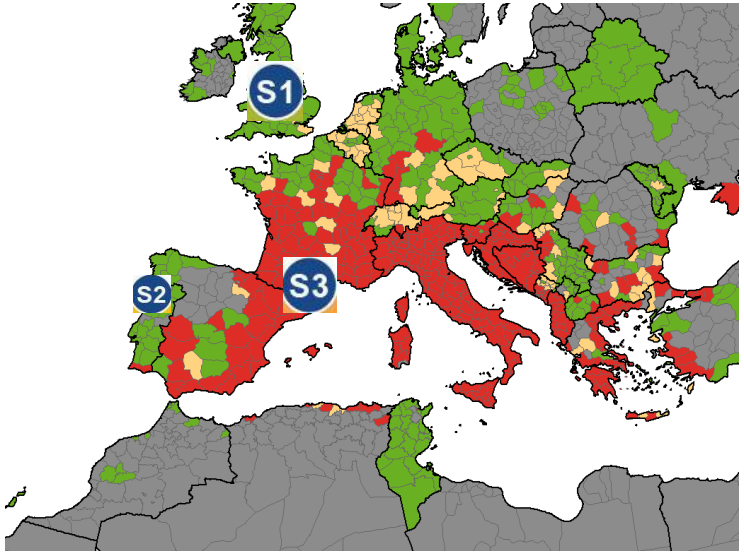


Scenarios for the Integrated Aedes Management (IAM) framework

These risk scenarios evolved with a non-linear transition!

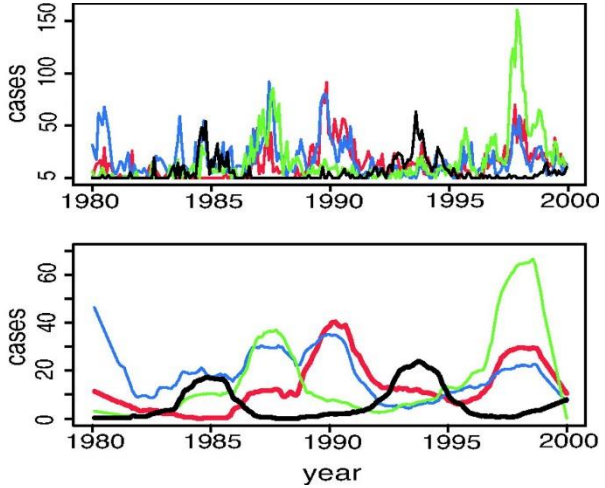
Sporadic transmission- irregulary, locally and unpredictably

Locally established – *Aedes* in less than 25 km2



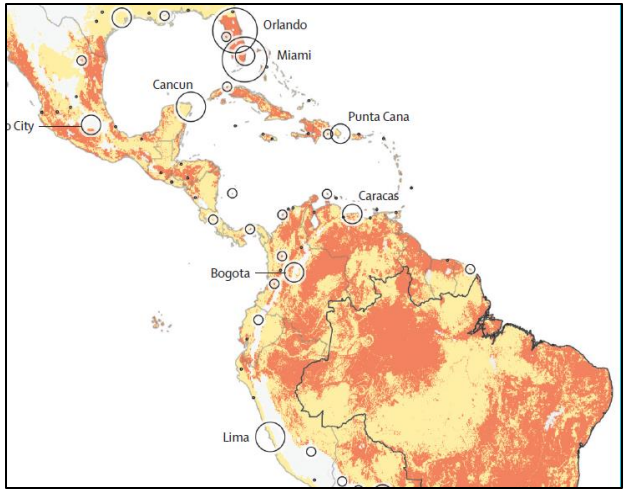
Ae. albopictus in Europe

S4 *Endemic transmission* – limited in space but not in time – dengue transmission season



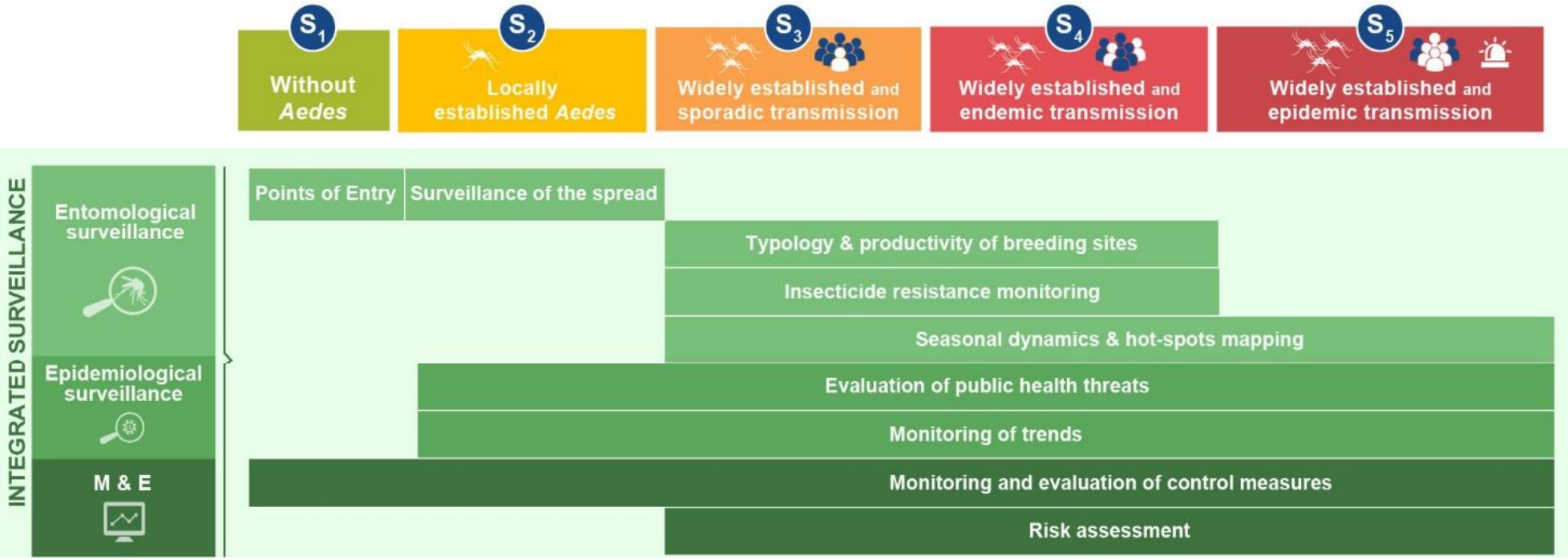
Bangkok (1980-2010)

S5 *Epidemic transmission* – limited in space and time – excess of normally expected cases



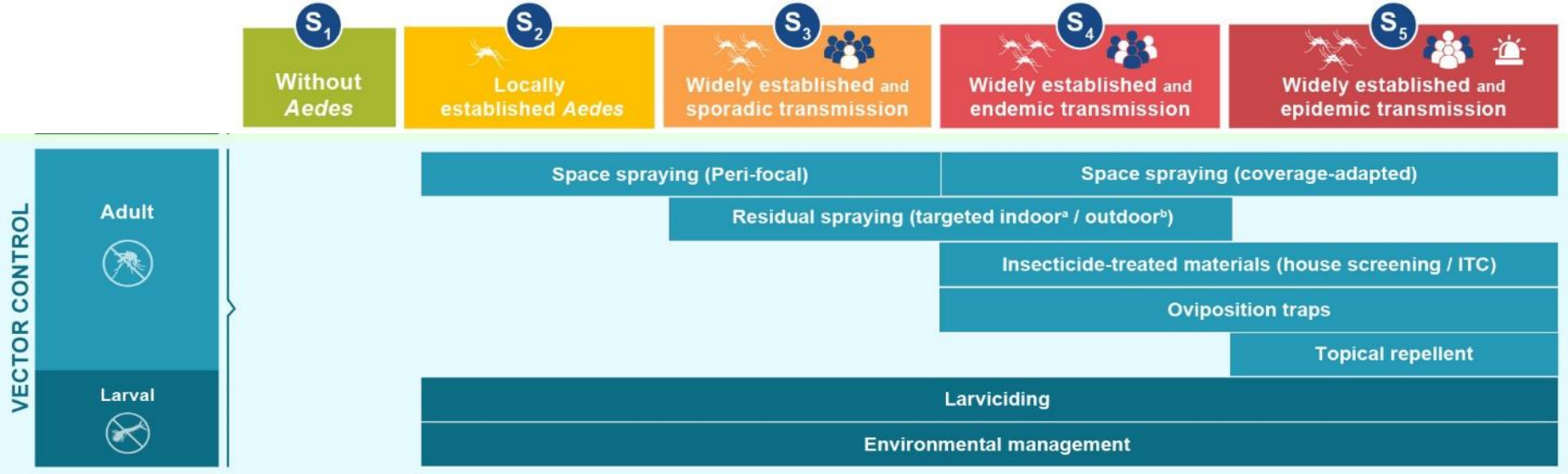
Zika (2016)

Entomological surveillance



Evaluation of interventions is critical!

Integrated vector control



- In routine or emergency
- Proactive rather than reactive
- Both larvae and adults vs prevalent paradigm targeting larvae
- Non-insecticide based tools

But…

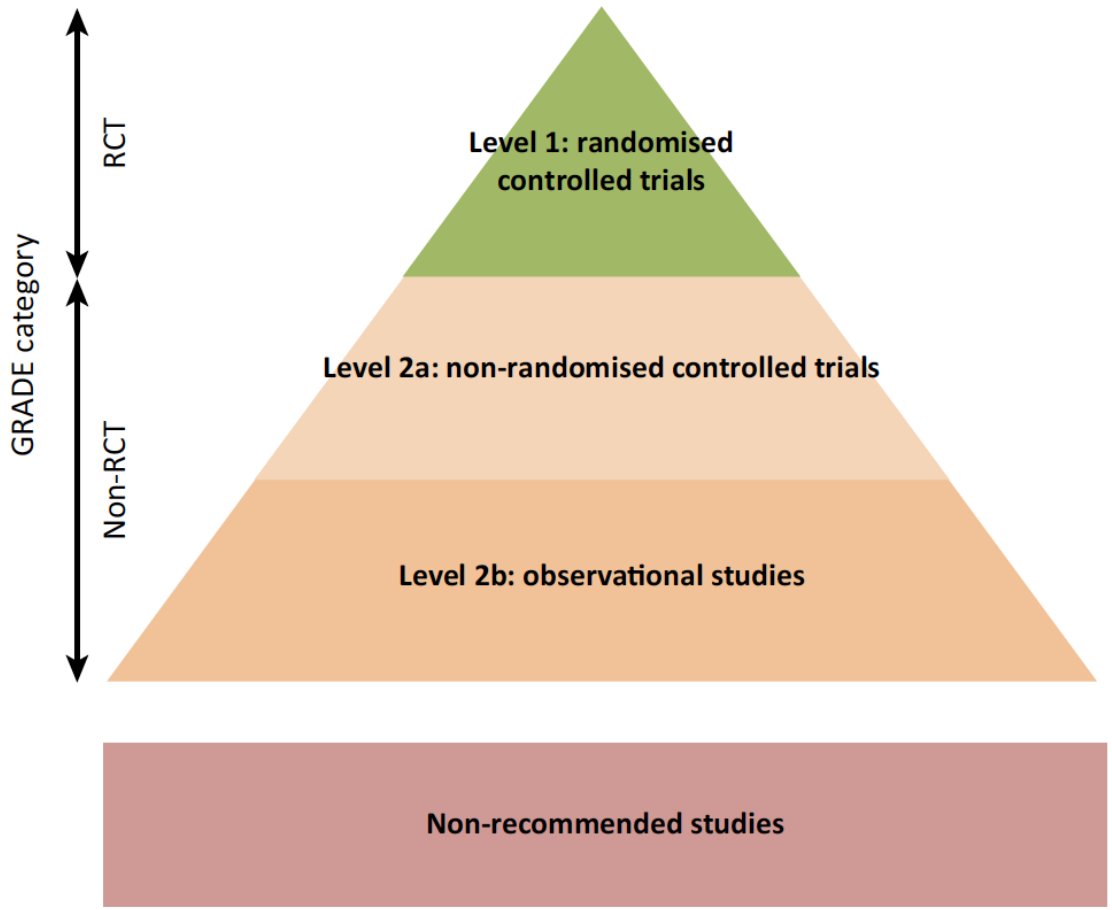
What is the strength of the evidence?

Data → Knowledge → Decision

What is the strength of the evidence?

Evidence-based vector control? Improving the quality of vector control trials

Anne L. Wilson[1], Marleen Boelaert[2], Immo Kleinschmidt[3], Margaret Pinder[1,4], Thomas W. Scott[5,6], Lucy S. Tusting[7], and Steve W. Lindsay[1]



HOW TO DESIGN VECTOR CONTROL EFFICACY TRIALS

Guidance on phase III vector control field trial design provided by the Vector Control Advisory Group

- **Randomised controlled** trial (individual or cluster randomised)
- **Randomised** cross-over study, step-wedge design, controlled before-and-after study, controlled time series or controlled interrupted time series

- **Non-randomised** cross-over study, step-wedge design, controlled before-and-after study or controlled interrupted time series

- **Case-control, cohort** or **cross-sectional** study

- **Non-randomised controlled trial** or **non-randomised controlled time series**
- Studies **without a control group** or **using a historical control group**

TRENDS in Parasitology

What is the strenght of the evidence?

Evidences

Examples of Epidemiological evidences of Integrated Aedes management

EVIDENCE-BASED DECISION MAKING

Epidemiological CRCT evidences for Community source reduction IVM Nicaragua and Mexico (Andersson et al., 2017)

Epidemiological CRCT evidences for Targeted Indoor Residual Spraying Mexico and Australia (Manrique-Saide et al., 2020)

Epidemiological CRCT evidences for *Wolbachia* population replacement Indonesia (Utarini et al., 2021)

Epidemiological CRCT evidences for Spatial repellent in Peru (Morrison et al., 2022)

Epidemiological observational evidences for Space Spraying in Peru (Stoddard et al., 2014)

Epidemiological observational evidences for Mass-trapping in Puerto Rico (Barrera et al., 2019)

Epidemiological observational evidences for Insecticide treated materials (Bowman et al., 2016)

Epidemiological observational evidences for Larviciding Pyriproxifen (Maoz et al., 2017)

What is the strenght of the evidence of innovative methods?

Wolbachia population replacement

The NEW ENGLAND JOURNAL of MEDICINE
ESTABLISHED IN 1812 JUNE 10, 2021 VOL. 384 NO. 23

Efficacy of Wolbachia-Infected Mosquito Deployments for the Control of Dengue

A. Utarini, C. Indriani, R.A. Ahmad, W. Tantowijoyo, E. Arguni, M.R. Ansari, E. Supriyati, D.S. Wardana, Y. Meitika, I. Ernesia, I. Nurhayati, E. Prabowo, B. Andari, B.R. Green, L. Hodgson, Z. Cutcher, E. Rancès, P.A. Ryan, S.L. O'Neill, S.M. Dufault, S.K. Tanamas, N.P. Jewell, K.L. Anders, and C.P. Simmons, for the AWED Study Group*

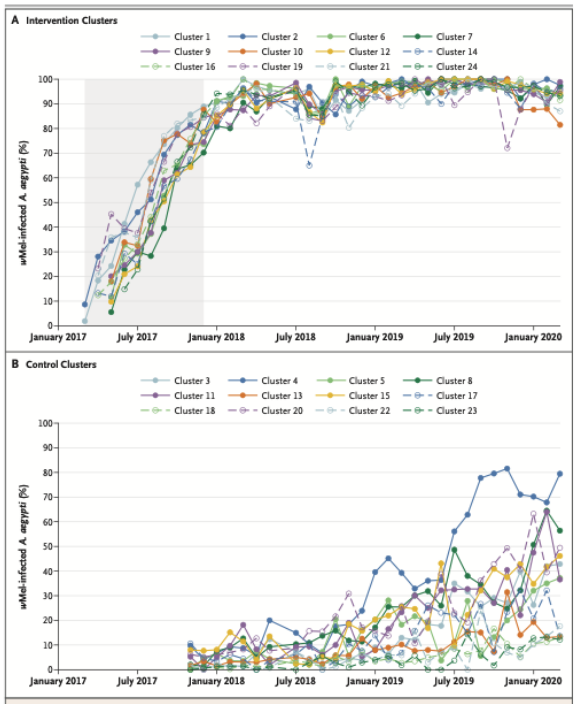
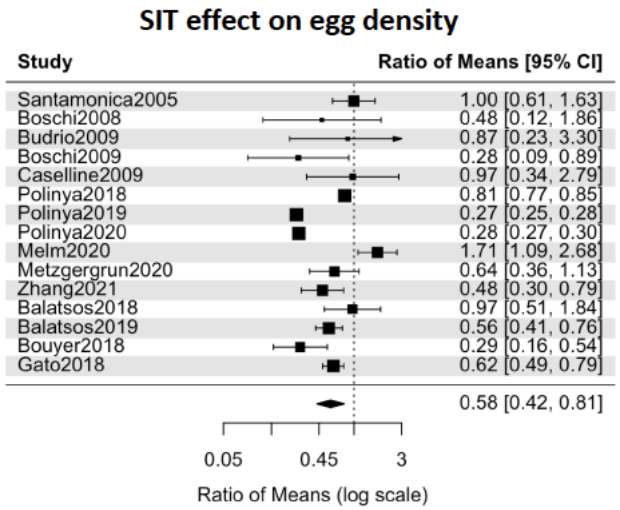


Figure 2. Introgression of *w*Mel into Local *A. aegypti* Mosquito Populations.
The lines in each panel indicate the percentage of *A. aegypti* infected with *w*Mel collected from traps in intervention clusters (Panel A) and control clusters (Panel B) each month from the start of deployments (March 2017) to the end of participant enrollment (March 2020). The shaded area in Panel A indicates the period from the first release in the first intervention cluster (March 2017) to the last release in the last intervention cluster (December 2017). There were 9 to 14 release rounds, with each round lasting 2 weeks, in each intervention cluster.

Sterile Insect technique (SIT) and Incompatible insect technique (IIT)

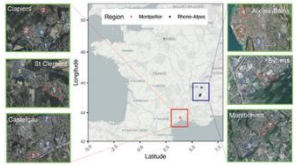
Meta-analysis: SIT- *Ae. albopictus*: egg reduction of 41.5% (19.4-51.6)

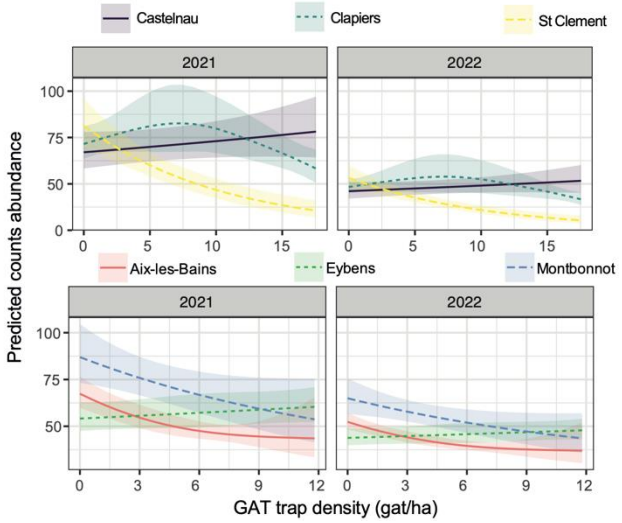


Mass-trapping

Current evidences of the efficacy of mosquito mass-trapping interventions to reduce *Aedes aegypti* and *Aedes albopictus* populations and *Aedes*-borne virus transmission

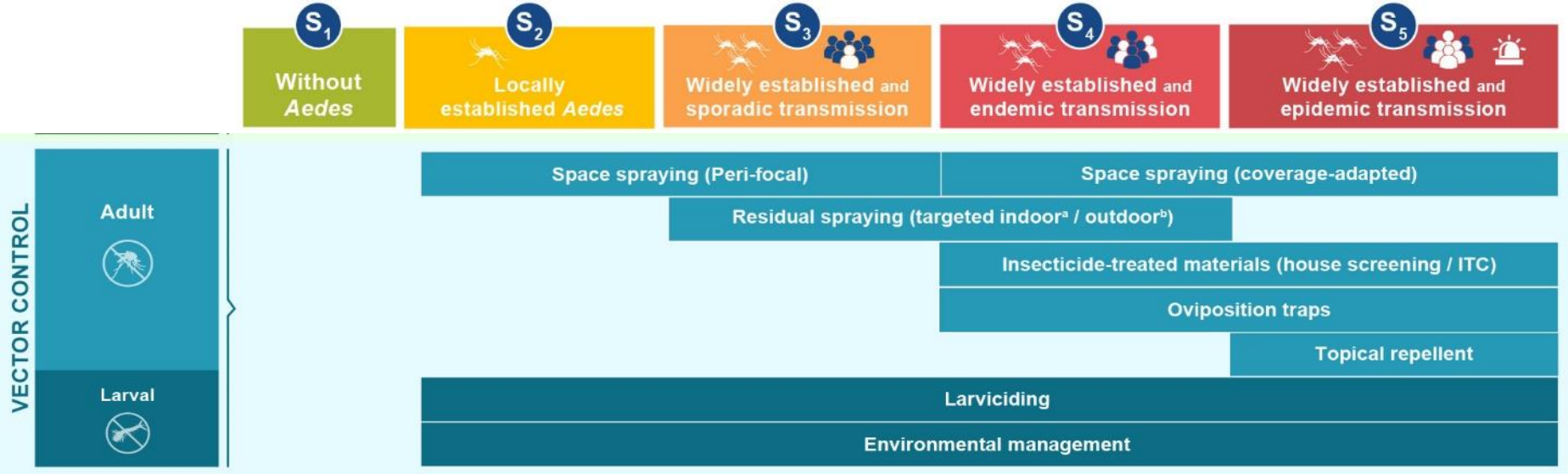
Ali Jaffal[1], Johanna Fite[1*], Thierry Baldet[2], Pascal Delaunay[3], Frédéric Jourdain[4,5], Ronald Mora-Castillo[6], Marie-Marie Olive[2,5], David Roiz[5]





Variability of *Ae. albopictus female* reduction of 25-64 %

Integrated vector control



Aedes albopictus – very limited entomological evidences

ORS: Outdoor Residual Spraying (vs ULV)

Source reduction and door-to-door

Larviciding (Cold-fogging Bti)

Mass-trapping (Gravid traps and adults)

SIT/Wolbachia

Auto-dissemination…

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

Gisela Chebabi Abramides[a], David Roiz[b], Raimon Guitart[c], Salvador Quintana[d], Irene Guerrero[e], Nuria Giménez[c,f,*]

emca European Mosquito Control Association

Guidelines for Mosquito Control in Built-Up Areas in Europe

Public health guidance to support the assessment of the risk of locally-acquired Aedes-borne viral diseases in the EU/EEA

ecdc EUROPEAN CENTRE FOR DISEASE PREVENTION AND CONTROL

Pitfalls for the evaluation of Aedes control trials

1. *What is exactly the research question?*
2. *Epidemiological outcomes (Phase III): dengue cases, serologies, seroincidence*
3. *Entomological outcomes: BG-Traps, HLR, ovitraps, hatching rate. Never larval indexes*
4. *Contemporary controls: is always possible? What is a comparison area?*
5. *Pre- and post-treatment measures*
6. *Size of the areas / buffer area?*
7. *Adult contamination effects / trap locations*
8. *Replications: number of clusters?*
9. *Power analysis*
10. *Randomization*
11. *Statistical analysis*
12. *Cost and cost-effectiveness*
13. *Publish positive and Negative results*

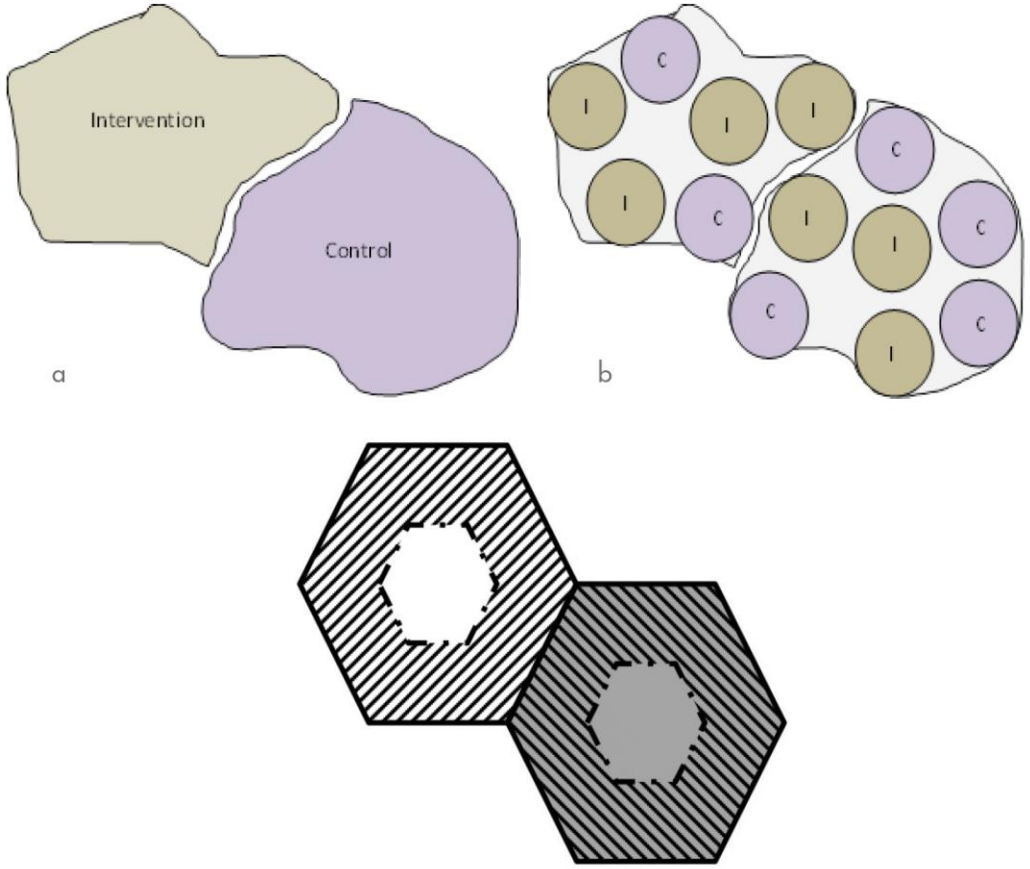
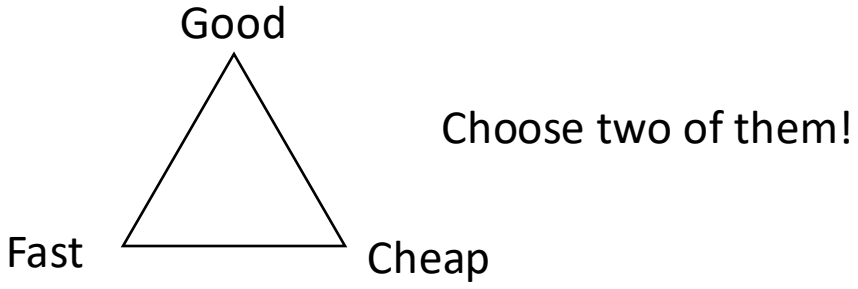


Figure 1. Schematic of two generic clusters demonstrating the 'fried-egg design'. The diagonal line patterns represent the 'buffer zones',

Cost-effectiveness of *Aedes* control strategies

If it's fast and cheap it won't be good.
If it is cheap and good, it will not be fast.
If it is fast and good, it will not be cheap!



In endemic areas, we can be cost-effective if we reduce Aedes populations by 70-90%, or even 50-70%*

1. **Strenght of the evidence of the effectiveness (entomological, epidemiological)**
2. **Economic costs and cost-effectiveness**
3. **Temporality/sustainability**
4. **Quality of delivery (coverage, delivery measures)**
5. **Environmental impact (non-target fauna)**
6. **Acceptability/legislation**
7. **Scenarios/ emergence vs routine / aegypti vs albopictus / DEN vs ZIKA/CHIK**

*Fitzpatrick et al., 2017

Social mobilisation

- Human behaviour is a common denominator of control programms
- Epidemiological and entomological evidences for community based control programs
- Communication for behavioural impact (COMBI)
- Adapted to scenario, context, socio-economic, culture and proactive

Multisectoral collaboration and supporting activities

- Inter-sectoral and inter-agency collaborations
- Ministries, NGOs, UN agencies, private sector, gender, religious and academic institutions
- As provision of reliable piped water, solid waste management.

A schematic guide for multisectoral collaboration

Ministry or organisation	Scenario	Activity	Rationale
Ministry of Public works and municipal authorities	S1, S2, S3 and S4	Provision of reliable piped water to households. Provision of sewerage connections. Solid waste management and disposal. Design and maintenance of street storm water drainage systems that do not harbour immature vectors.	Removal of potential *Aedes* mosquito larval development habitats can reduce adult numbers and virus transmission rates.
Ministry of Housing	S3 and S4	Develop and enforce housing and building codes mandating installation of screening, dependable water supply, waste management and disposal and rainwater runoff control in new housing developments.	Reduce biting of humans by installing screens to prevent entry to houses and buildings. Reduce standing water to prevent immature development.
Ministry of Education	S3 and S4	Incorporate information on *Aedes*-borne diseases, vectors, transmission and prevention into school curricula and teach hygienic behaviour.	Empower children with knowledge and skills to reduce mosquito populations and virus transmission.
	S3, S4 and S5	Participation of school children in larval surveys, source reduction and larviciding.	
Ministry of Tourism	S3 and S4	Reduce aquatic habitats in and around hotels, community gathering places, markets, etc.	Reduce virus transmission.
	S5	Communicate rapidly to holiday	Supports rapid implementation of

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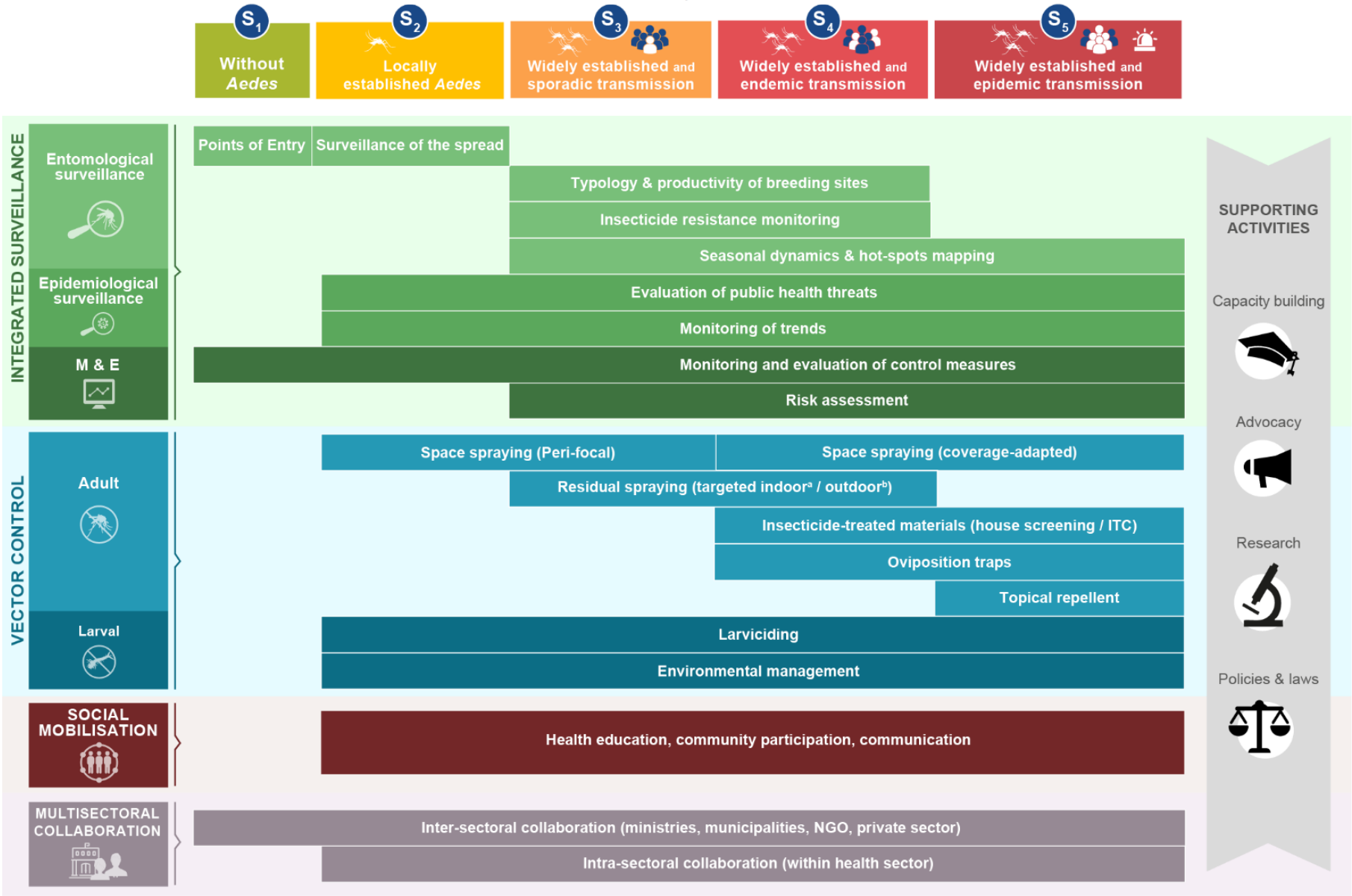


Aedes-borne diseases they also cause a global economic burden

The economic burden needs to be appropriately quantified to facilitate the management decisions. But the **economic impacts have not been sufficiently studied**

Since 2016, the InvaCost initiative has generated a database of the reported costs of biological invasions, including mosquitoes. *Ae. aegypti* and *Ae. albopictus* among **the costliest invasive species worldwide**

High and rising economic costs of biological invasions worldwide

nature

https://doi.org/10.1038/s41586-021-03405-6
Received: 8 April 2020

Christophe Diagne[1], Boris Leroy[2], Anne-Charlotte Vaissière[1], Rodolphe E. Gozlan[3], David Roiz[4], Ivan Jarić[5,6], Jean-Michel Salles[7], Corey J. A. Bradshaw[8] & Franck Courchamp[1]

nature COMMUNICATIONS

ARTICLE

Received 13 Feb 2016 | Accepted 18 Aug 2016 | Published 4 Oct 2016 DOI: 10.1038/ncomms12986 OPEN

Massive yet grossly underestimated global costs of invasive insects

Corey J.A. Bradshaw[1,2], Boris Leroy[1,3], Céline Bellard[1,4], David Roiz[5,*], Céline Albert[1,*], Alice Fournier[1], Morgane Barbet-Massin[1], Jean-Michel Salles[6], Frédéric Simard[5] & Franck Courchamp[1,7,8]

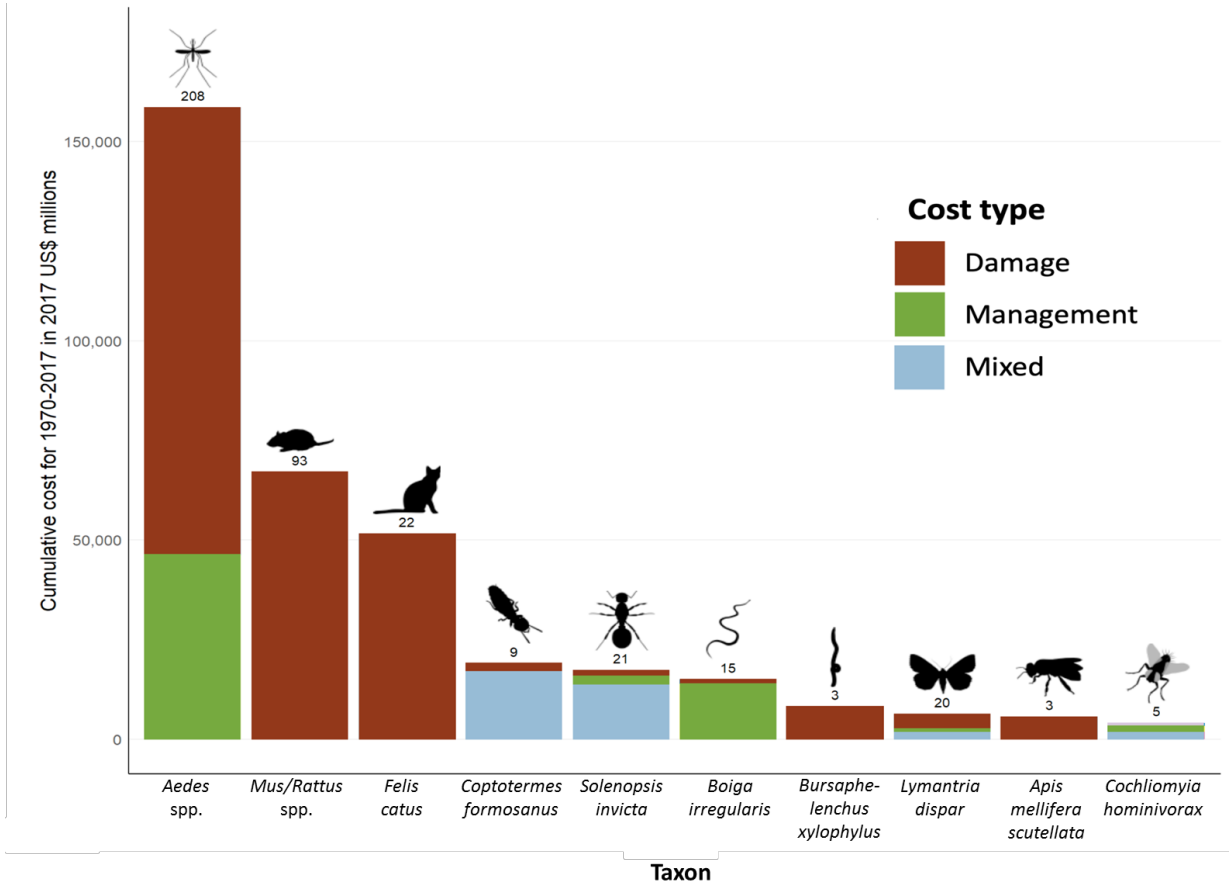
SCIENTIFIC DATA

OPEN DATA DESCRIPTOR

InvaCost, a public database of the economic costs of biological invasions worldwide

C. Diagne[1], B. Leroy[2], R. E. Gozlan[3], A.-C. Vaissière[1], C. Assailly[1,4], L. Nuninger[1,4], D. Roiz[4], F. Jourdain[4,5], I. Jarić[4,6] & F. Courchamp[1]

InvaCost



So, we focused on a more complete research of *REPORTED costs* for both *Aedes* mosquitoes and *Aedes*-borne diseases

The rising global economic costs of *Aedes*-borne diseases and *Aedes* mosquitoes

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journal homepage: www.elsevier.com/locate/scitotenv

The rising global economic costs of invasive *Aedes* mosquitoes and *Aedes*-borne diseases

David Roiz [a,b,*,1], Paulina A. Pontifes [a,b,1], Fréderic Jourdain [a,c], Christophe Diagne [e], Boris Leroy [f], Anne-Charlotte Vaissière [d,g], María José Tolsá-García [a,b], Jean-Michel Salles [h], Fréderic Simard [a], Franck Courchamp [d]

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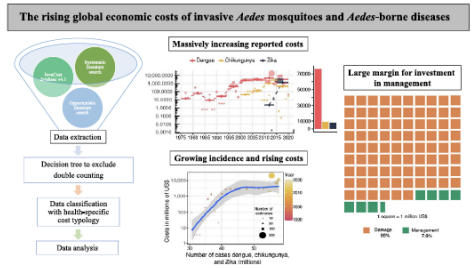
HIGHLIGHTS

- Dengue, Zika and chikungunya are transmitted by *Aedes aegypti* and *Aedes albopictus*.
- These invasive species carry a significant but not well-characterized economic cost.
- Our study reports costs from 166 countries and territories, spanning 45 years.
- The cumulative reported cost amounted to at least US$ 94.7 billion.
- Costs are increasing and only a modest proportion (1/10) is invested in prevention.

GRAPHICAL ABSTRACT



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Aedes aegypti
Aedes albopictus
Dengue
Zika

ABSTRACT

Invasive *Aedes aegypti and Aedes albopictus* mosquitoes transmit viruses such as dengue, chikungunya and Zika, posing a huge public health burden as well as having a less well understood economic impact. We present a comprehensive, global-scale synthesis of studies reporting these economic costs, spanning 166 countries and territories over 45 years. The minimum cumulative reported cost estimate expressed in 2022 US$ was 94.7 billion, although this figure reflects considerable underreporting and underestimation. The analysis suggests a 14-fold increase in costs, with an average annual expenditure of US$ 3.1 billion, and a maximum of US$ 20.3 billion in 2013. Damage and losses were an order of magnitude higher than investment in management, with

A **pionnering and exhaustive global** study of reported costs

166 countries and territories covering **45 years**

Data to **inform evidence-based policy** into the nature and distribution of *Aedes*-borne costs.

PRISMA Methodology

Methodology to **avoid double-counting**

Reported evidence from high-reliability records

Data Compilaton → Data Extraction → Data treatment → Data analysis

DRYAD

Who we

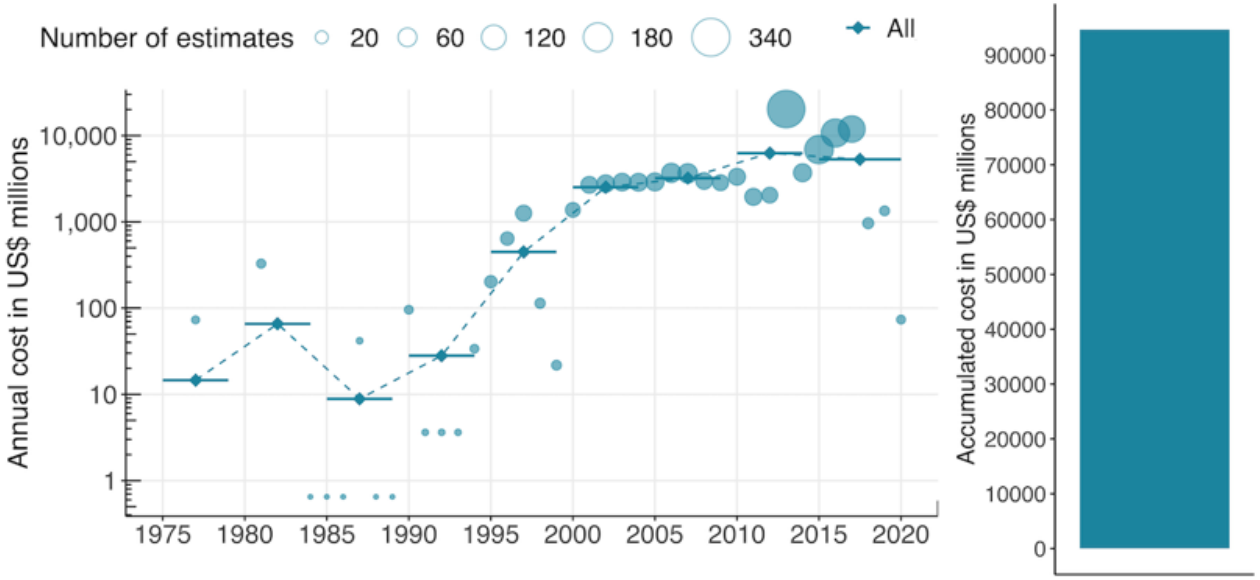
The rising global economic costs of invasive Aedes mosquitoes and Aedes-borne diseases

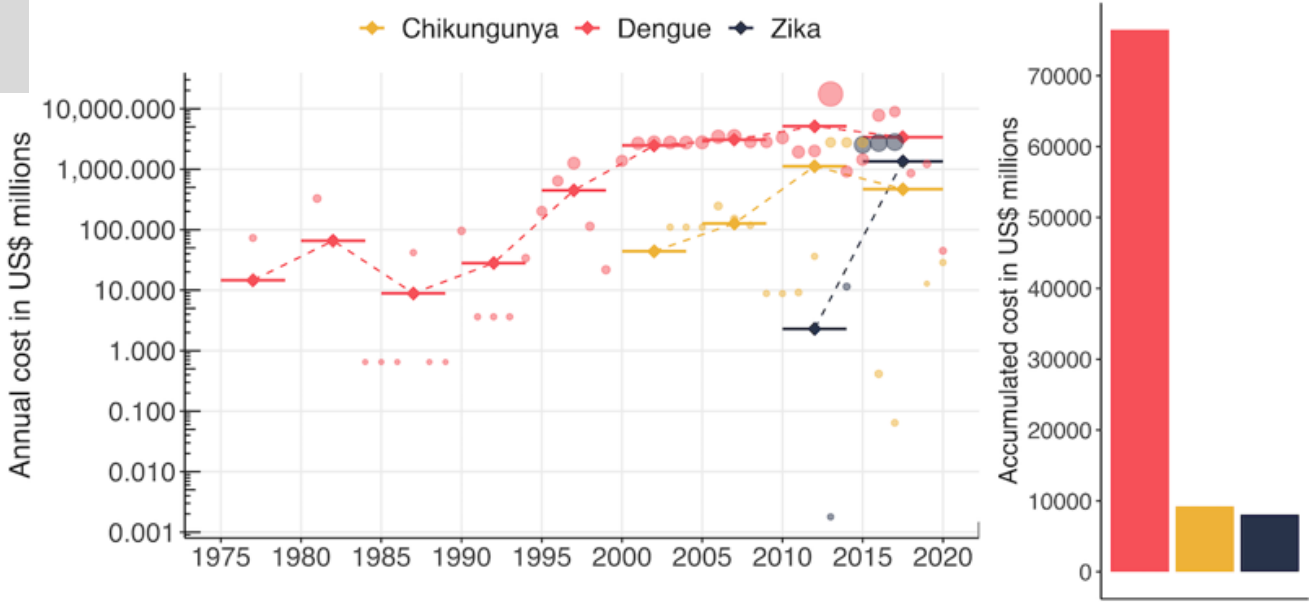
What are the types of costs and who paid for them?

	Damage	Management	Losses	Non-market costs
Health Providers (public/private)	Direct medical costs Non-medical costs	Surveillance Vector control Prevention Blood and organ screening Vaccination		
Individuals	Out-of-pocket costs Indirect costs (wage losses, debt)	Personal protection		Quality of life
Community	Indirect costs lost productivity, disability benefits	Research and funding Community-based vector control	Tourism Trade losses (commercial) Economic growth	

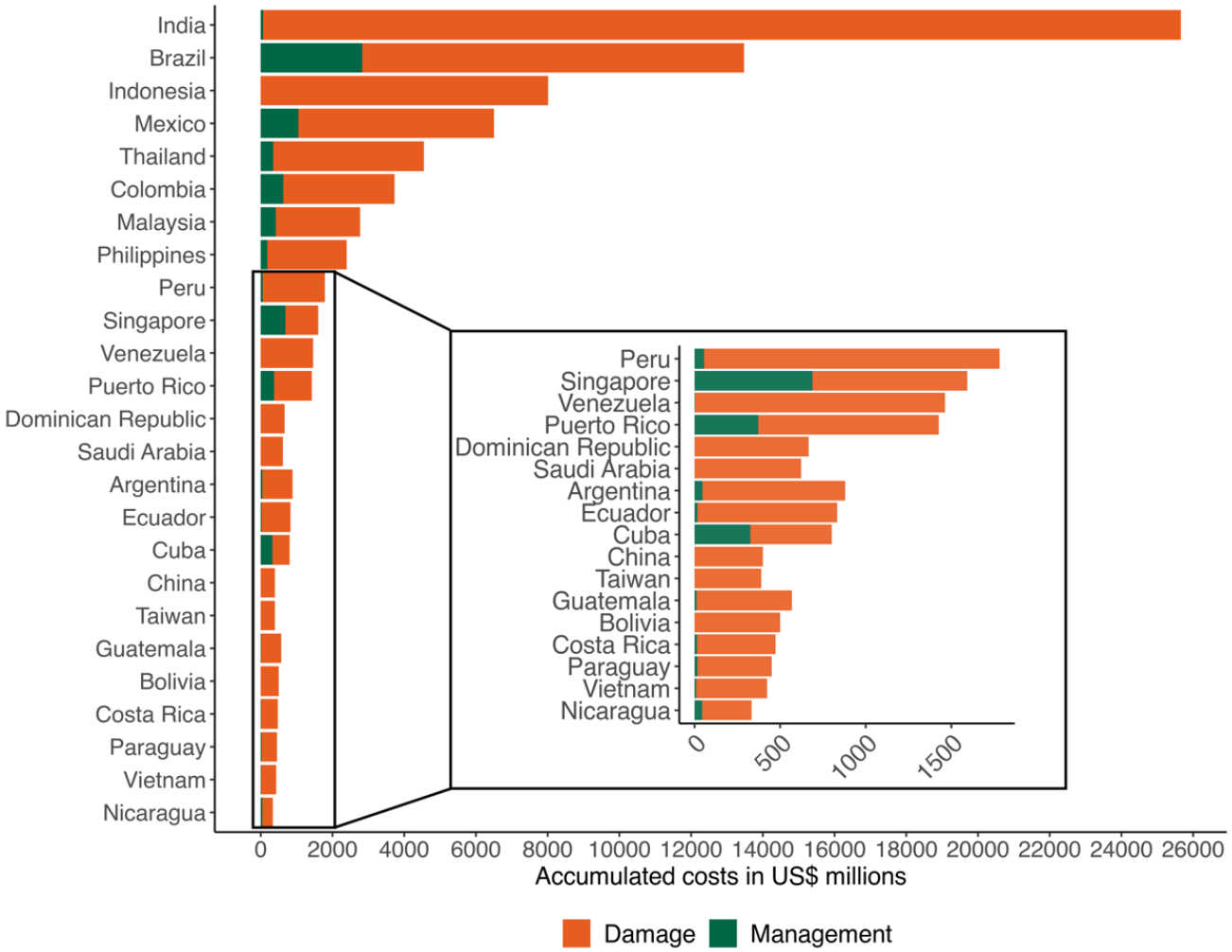
Massively increasing reported global costs

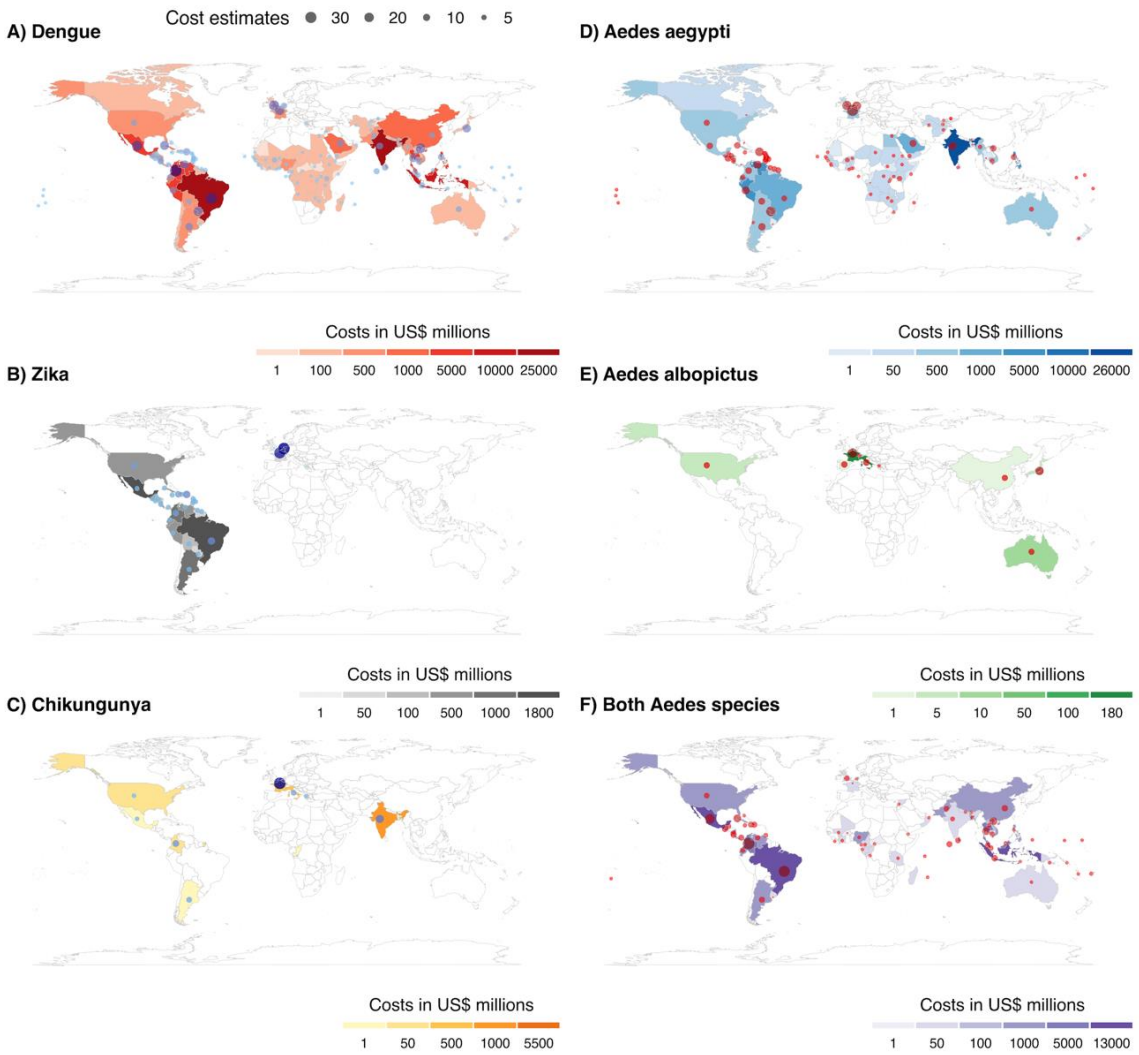
- The **minimum** estimate of reported cumulative costs is $94.7 billion (1975-2020)
- The average **annual** cost is $3.1 billion, with a peak of $20.3 billion in 2013
- Costs **multiplied by 14** in 2 decades (1995 to 2014)
- The costs of the longer-term consequences of chikungunya and zika (microcephaly, osteoarthritis, etc.) are estimated at **$318 billion**.
- Costs are largerly **underestimated and underreported**





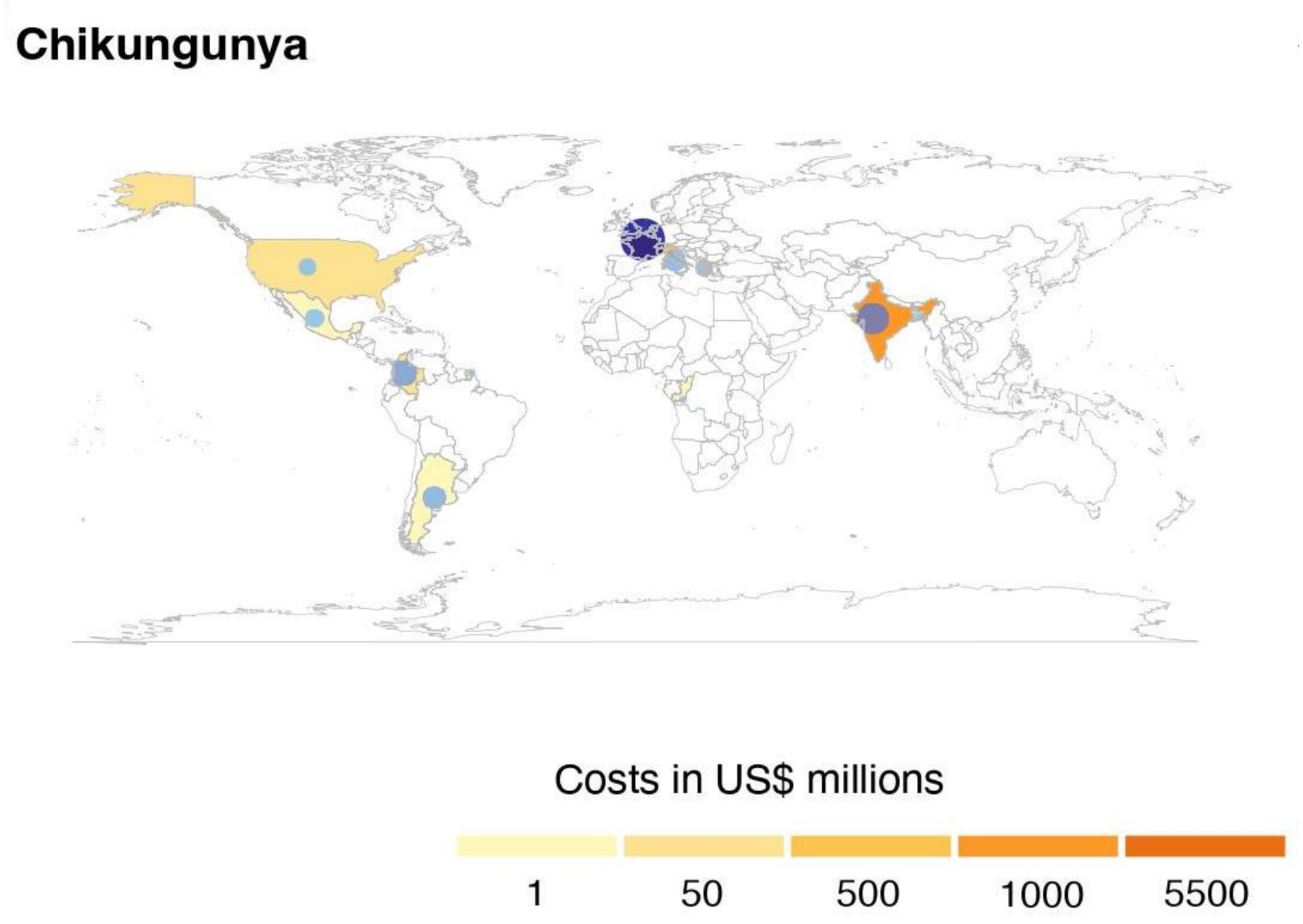
Geographical breakdown of reported costs



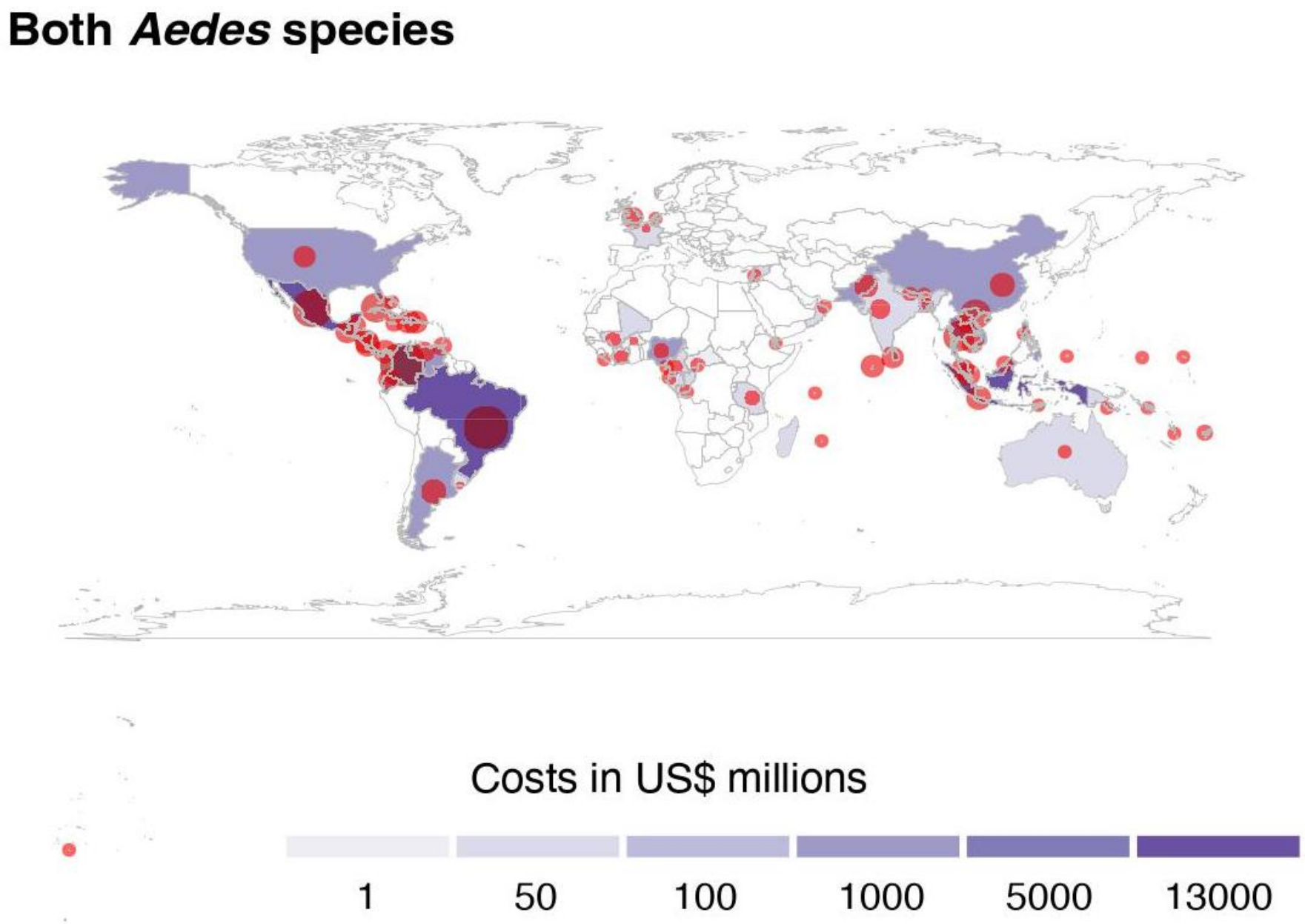


Within the same order of magnitude as other large-scale global estimates (Shepard et al., 2016; Selck et al., 2014; World Bank, 2018)

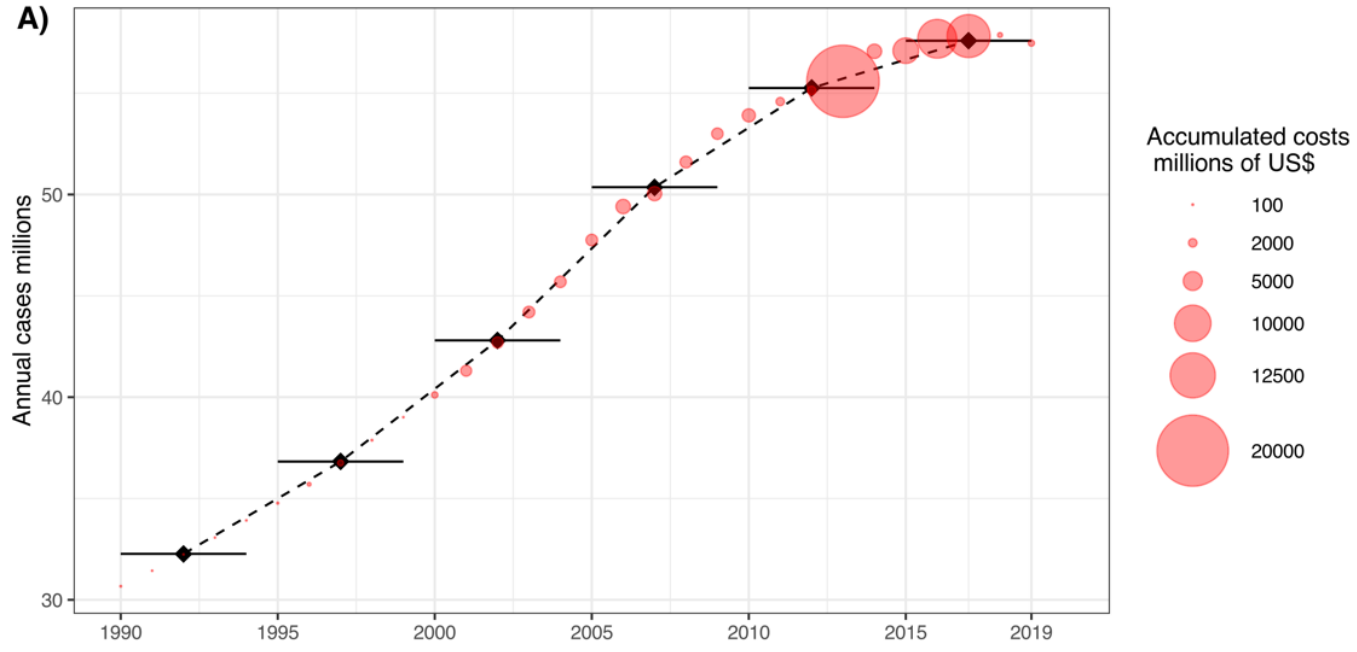
Geographical breakdown of reported costs

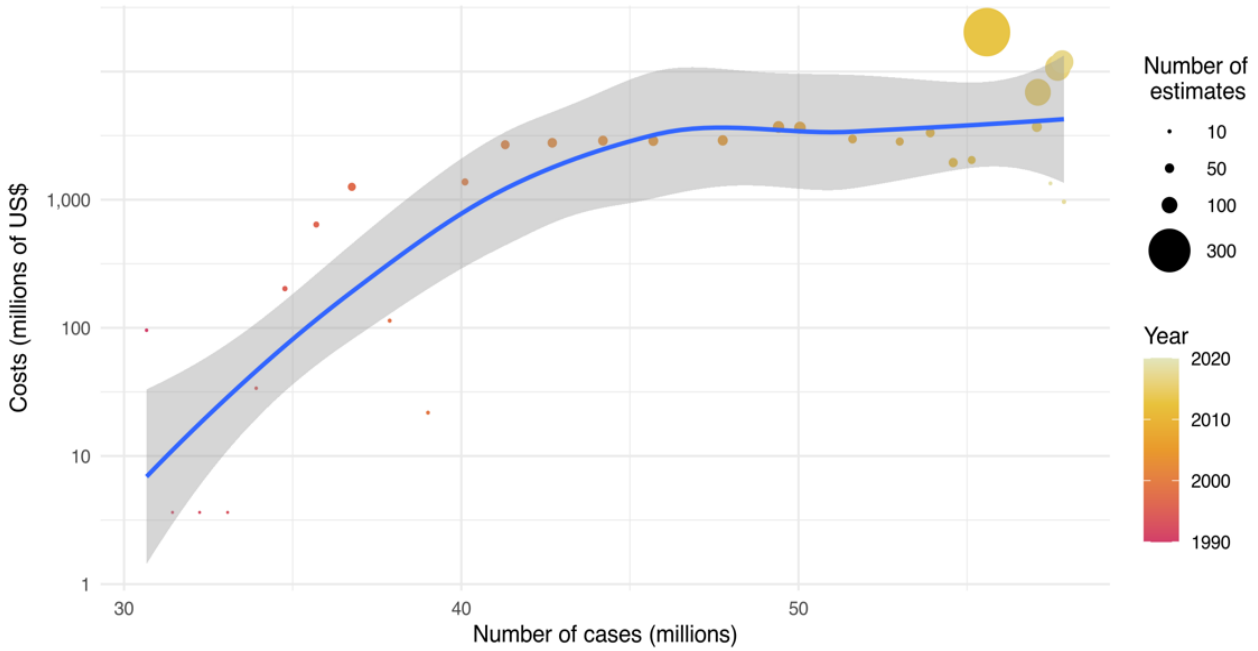


Geographical breakdown of reported costs



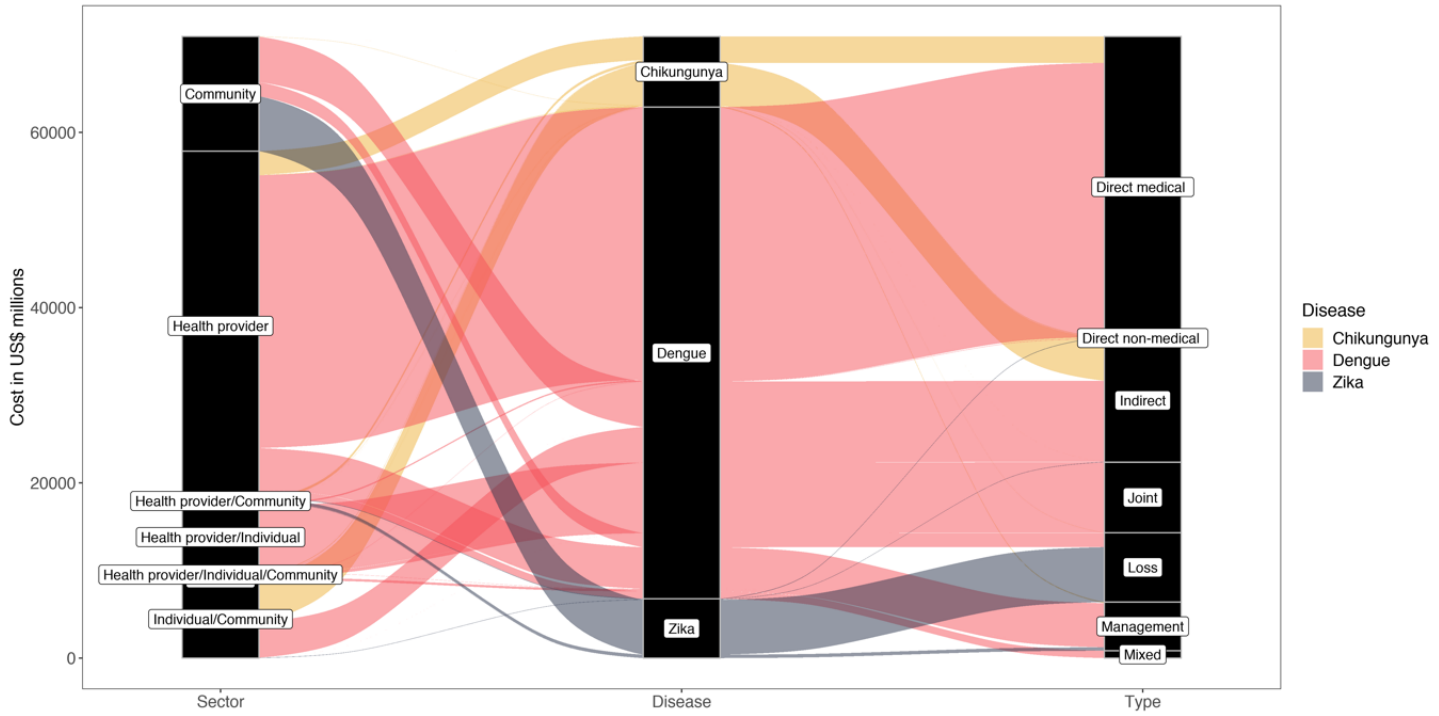
How do the costs increase in relation to cases?

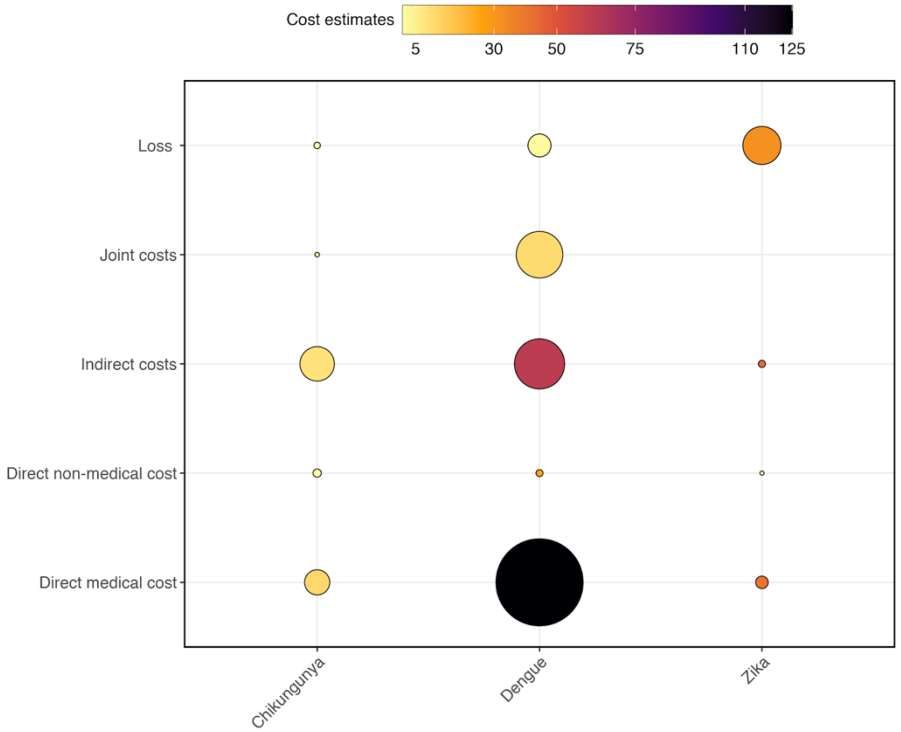




For example, dengue fever has increased by 85.5% over the last 30 years (Yang et al., 2021)

Who pays?

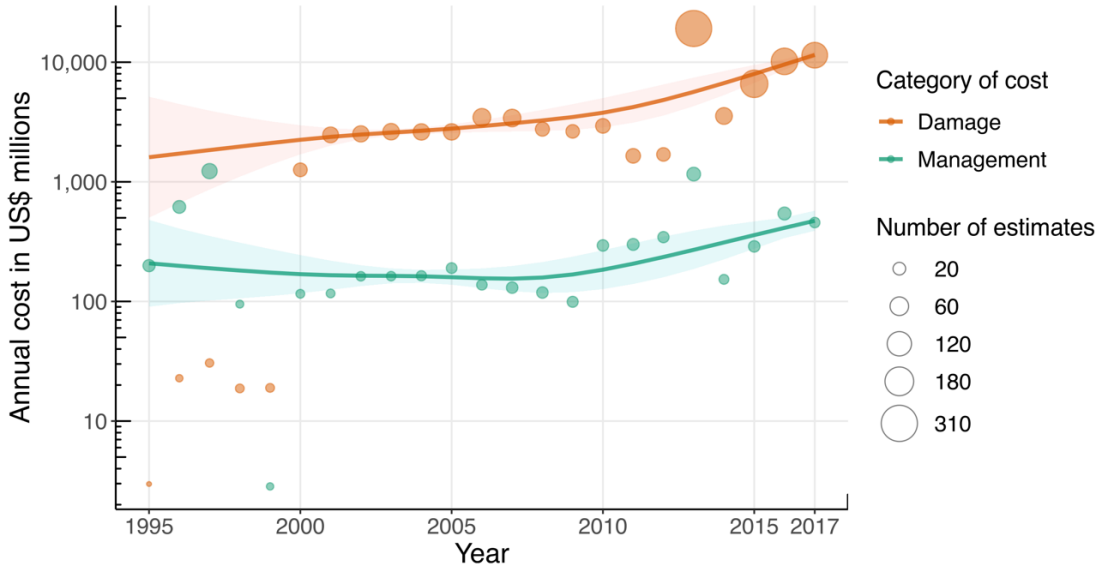


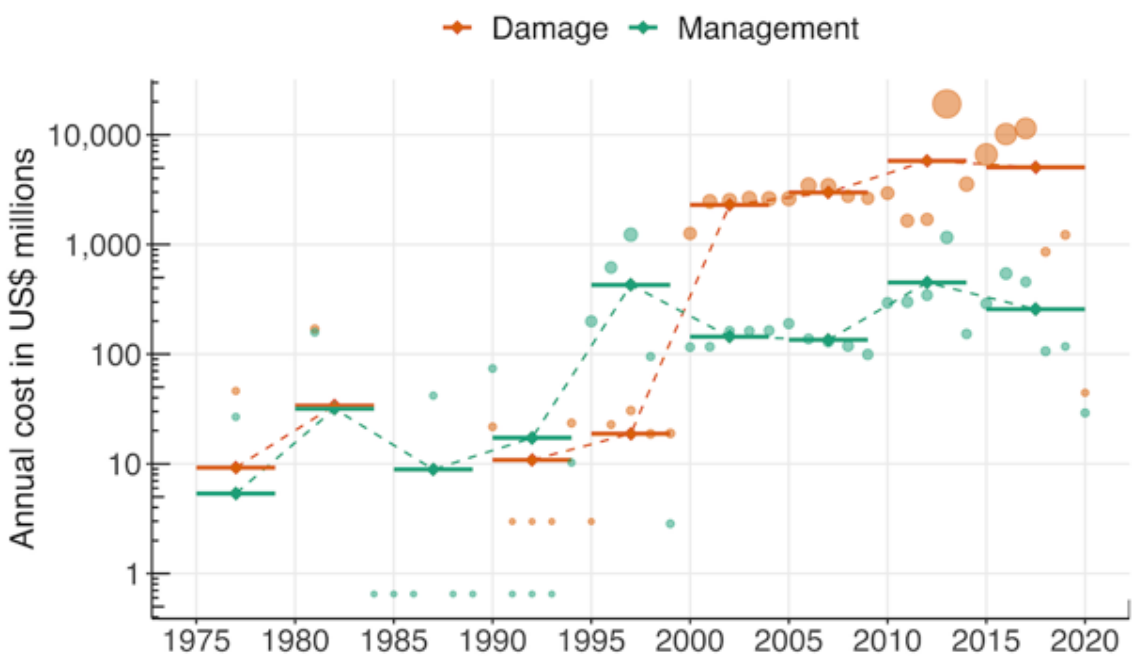


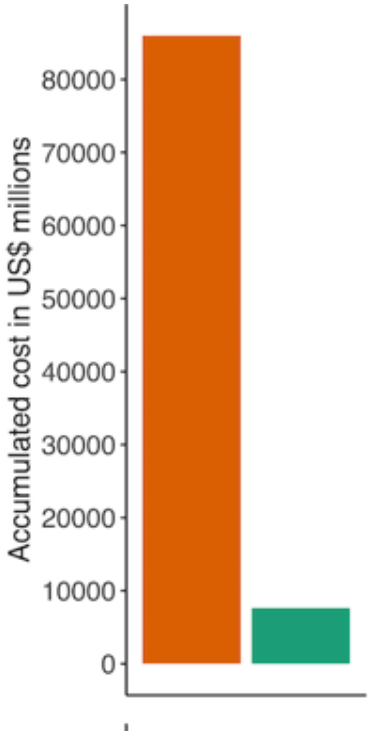
- Healthcare providers absorb the majority of direct medical costs due to dengue
- Indirect medical costs (after-effects, productivity, etc.), which occur over the long term and are more difficult to quantify, are borne by individuals and the community
- The losses borne mainly by the community (tourism, trade, economic growth) are difficult to quantify
- A disproporcionate burden among impoverished population without access to public health services, reinforcing the poverty trap

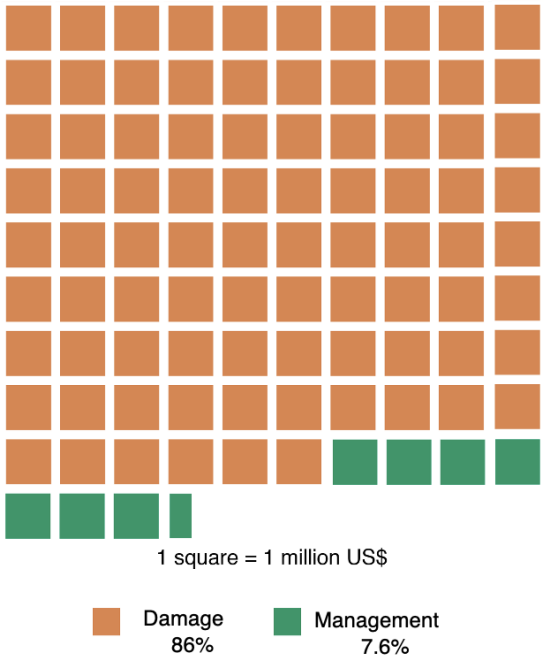
Relationship damage vs management

- Expenditure on damage and losses is <u>10 times higher than the investment in management</u>, surveillance and control.
- Only 10% has been allocated to management and prevention

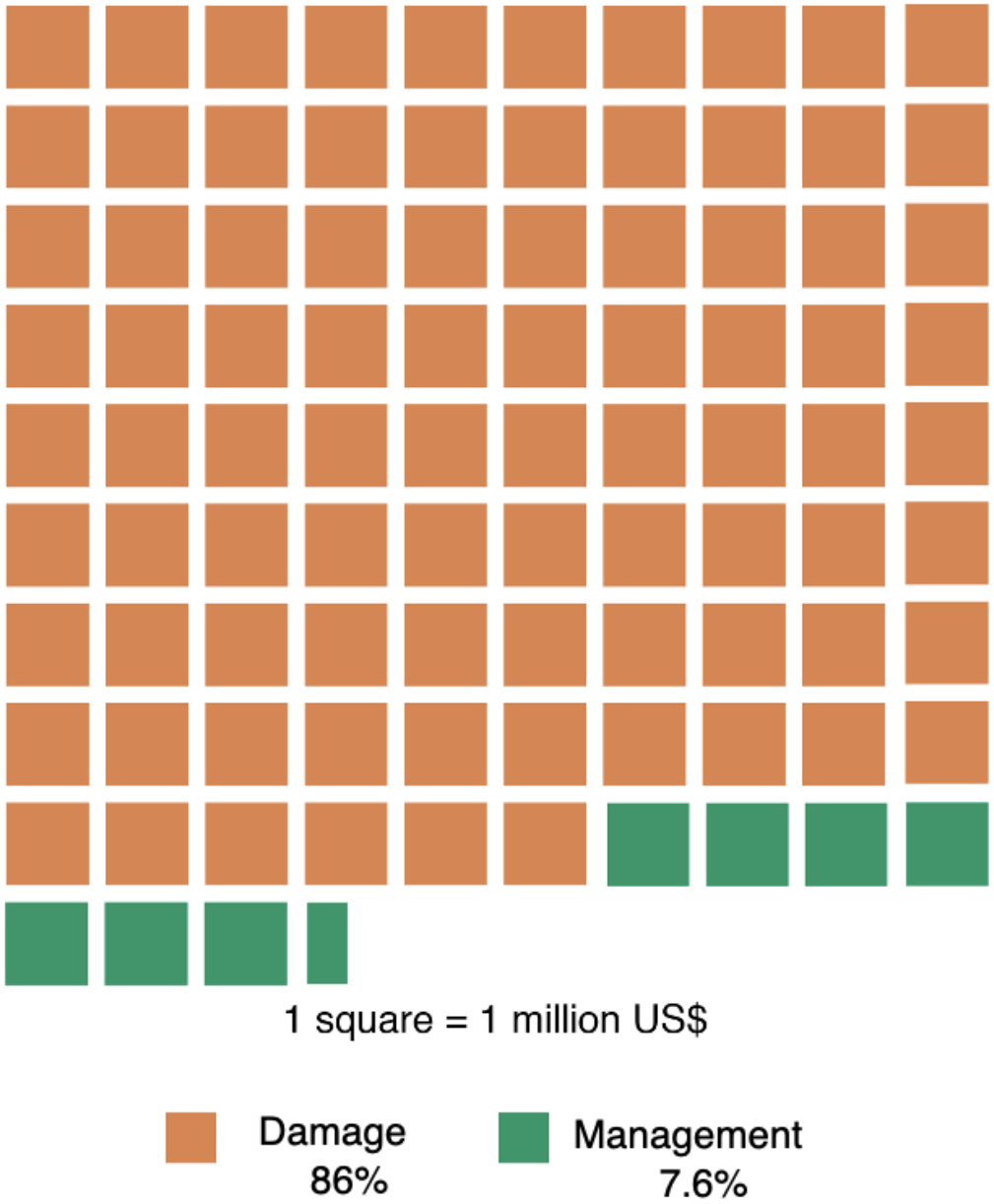








Relationship damage vs management



A limited investment in mosquito control
Potential benefits are the avoided costs
Effective control actions could reduce damage in a long-term

Early action with proactive (preventive) strategies rather than reactive (emergency) responses or even inaction

Effective, sustainable and integrated management would be beneficial for public health and human societies

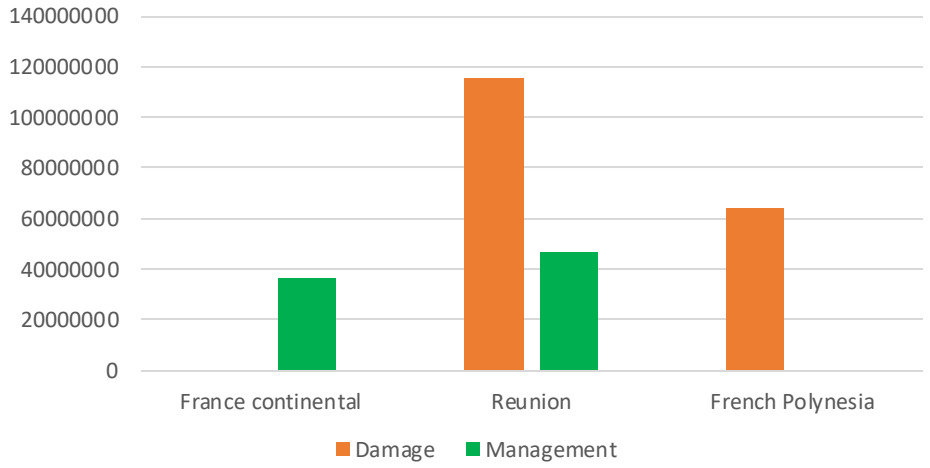
The magnitude of the relationship depends –in part- on the scenario

Management > Damage

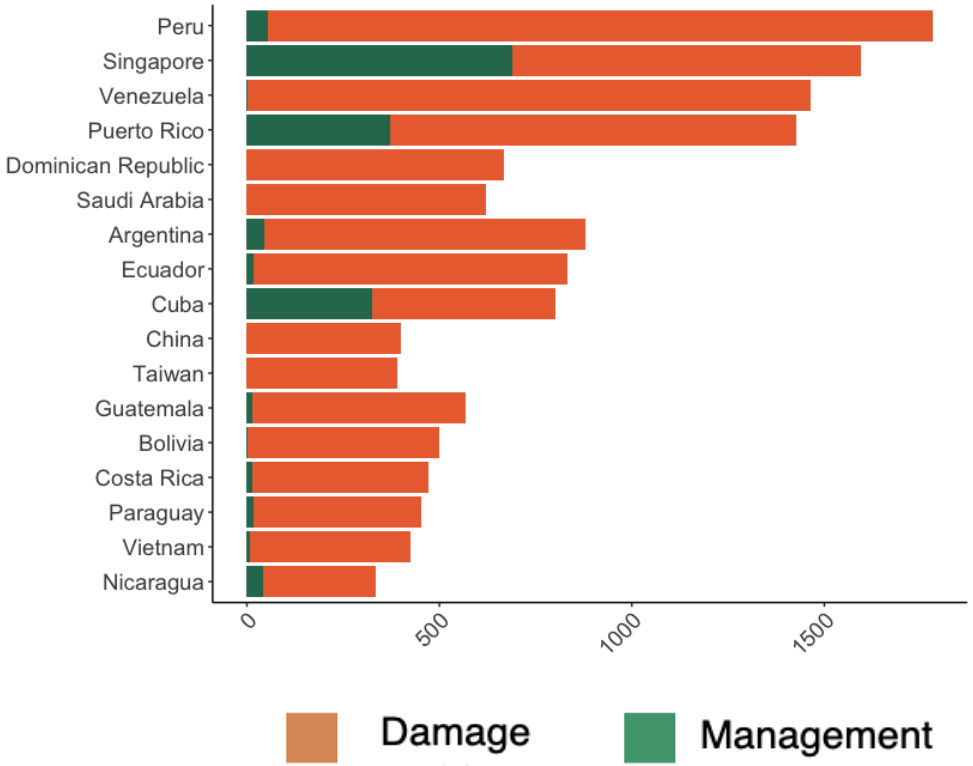
Damage > Management

Losses and Damage > Management

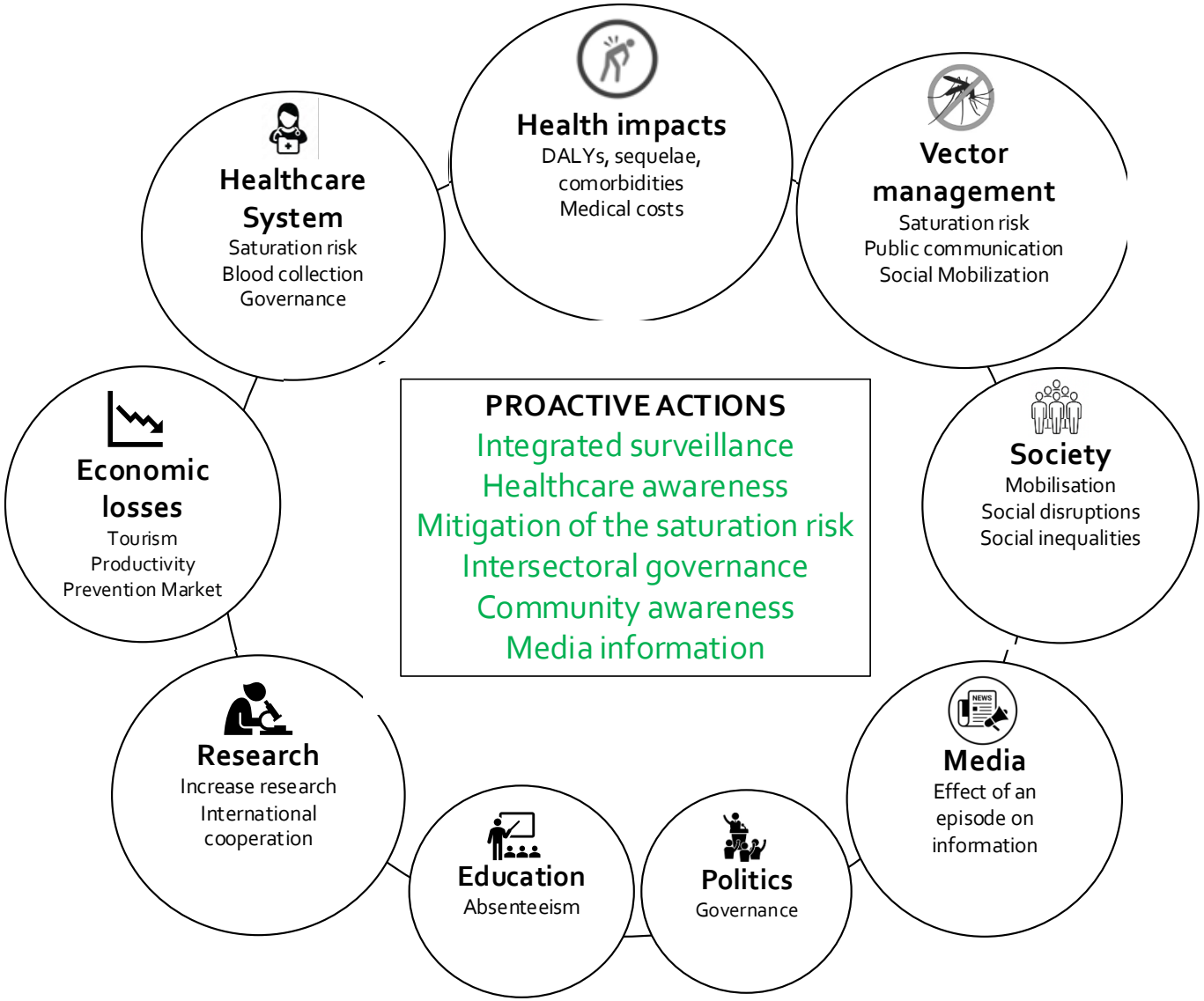
We can have a preliminar idea based on the diferences in magnitudes, but the benefits of avoiding cases are at a short- and at a long- term

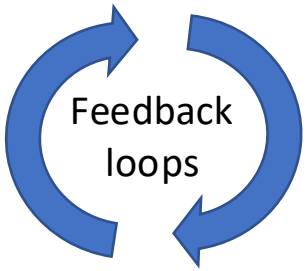


Example of France 1990-2020



Multi-sectoral impacts





anses

Moustique tigre en France hexagonale : risque et impacts d'une arbovirose

Avis de l'Anses
Rapport d'expertise collective

Juillet 2024

GT ARBO

Marie-Claire Paty , Bénédicte Apouey , Clémentine Calba , Éric Cardinale , Carine Milcent , David Roiz , Elodie Rouviere , Jean-Michel Salles , Frédéric Simard, Yannick Simonin, Josselin Thuilliez, Émeline Barrès , Véronique Raimond , Johanna Fite, Florence Étoré, Karine Fiore

Take home messages

- To strengthen robust evidences for innovative non-insecticide approaches
- Entomological and epidemiological outputs and risk thresholds
- Cost-effectiveness / temporality / acceptability/ quality of delivery
- Sustainability/Proactive/Synergies/ No magic bullets
- Locally-adapted/ focus on high risk areas (hot-spots)
- Highly increasing underreported economic costs
- Limited investment in vector control campaigns
- Multi-sectoral impacts on the society, media, politics, losses…

We need more operational research to foster evidence-based vector control guidance tailored to local settings and available resources

Thanks

david.roiz@ird.fr

David Roiz

FOLLOWING

Institut de Recherche pour le Développement (IRD)-MIVEGEC.
Verified email at ird.fr - Homepage

Ecology of mosquito-borne … Aedes-borne diseases control Aedes albopictus emerging diseases

TITLE	CITED BY	YEAR
High and rising economic costs of biological invasions worldwide C Diagne, B Leroy, AC Vaissière, RE Gozlan, D Roiz, I Jarić, JM Salles, ... Nature 592 (7855), 571-576	1236	2021
Massive yet grossly underestimated global costs of invasive insects CJA Bradshaw, B Leroy, C Bellard, D Roiz, C Albert, A Fournier, ... Nature communications 7 (1), 12986	960	2016
First record and establishment of the mosquito *Aedes albopictus* in Spain C Aranda, R Eritja, D Roiz Medical and veterinary entomology 20 (1), 150-152	304	2006
Integrated *Aedes* management for the control of *Aedes*-borne diseases D Roiz, AL Wilson, TW Scott, DM Fonseca, F Jourdain, P Müller, ... PLoS neglected tropical diseases 12 (12), e0006845	297	2018

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Aedes albopictus management: some Italian experience

par Romeo Bellini

Centro Agricoltura Ambiente Giorgio Nicoli

Aedes albopictus management: some Italian experience

Romeo Bellini
Centro Agricoltura Ambiente «G. Nicoli»

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Liberté
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anrs MALADIES INFECTIEUSES ÉMERGENTES Inserm

Arbo-France
Réseau Français d'étude des arboviroses

Journées scientiques :
Moyens innovants de lutte contre les vecteurs d'arbovirus.
Institut Pasteur, Paris
23 & 24 juin 2025

MINISTRY OF HEALTH

National plan for prevention, surveillance and answer to arboviruses 2020-2025

WEST NILE
USUTU
CHIKUNGUNYA
DENGUE
ZIKA
TBE
TOSV

Regione Emilia-Romagna

SERVIZIO SANITARIO REGIONALE
EMILIA-ROMAGNA

Regione del Veneto

Il portale della Regione del Veneto

REGIONE AUTONOMA
FRIULI VENEZIA GIULIA

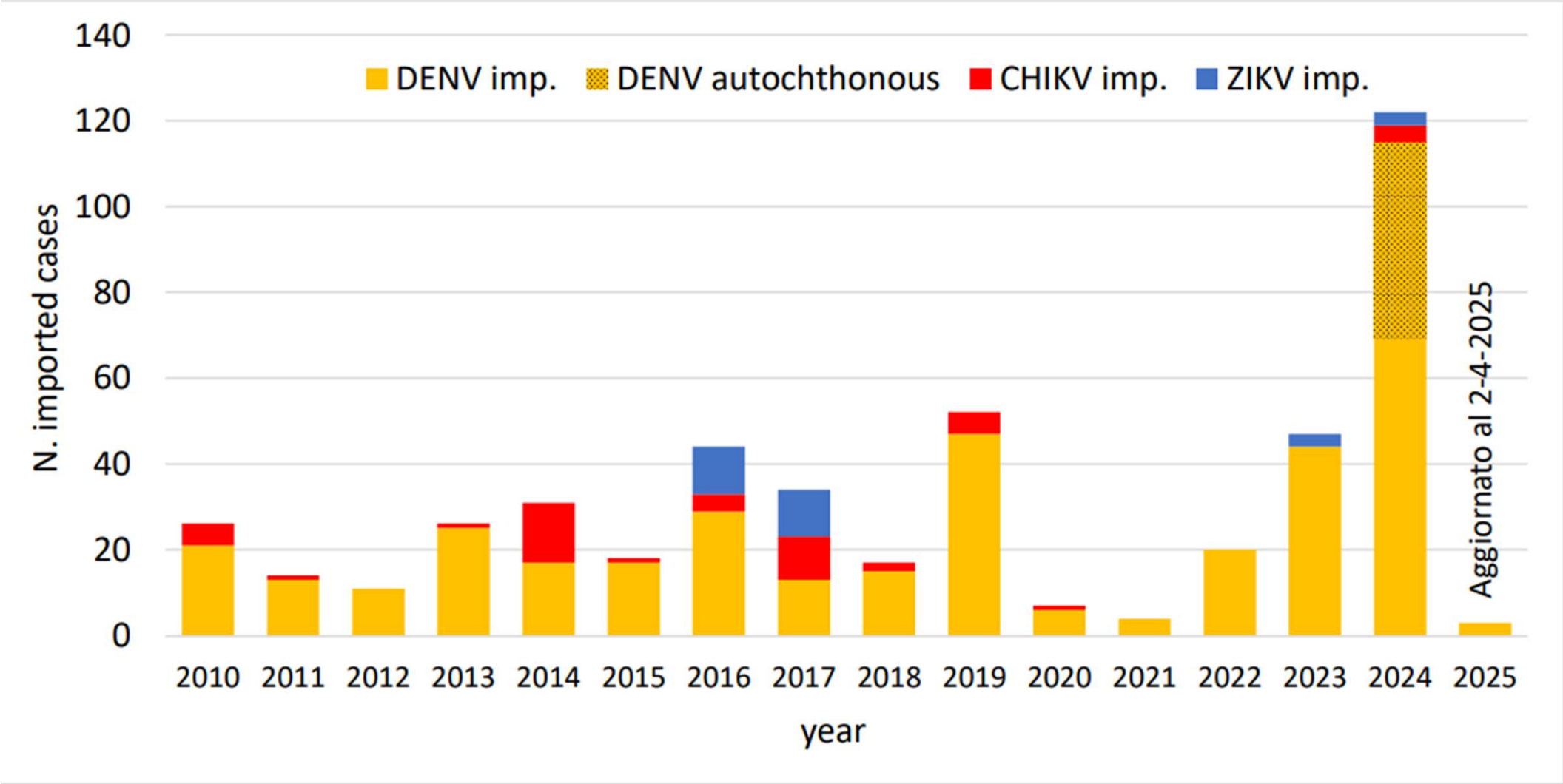
REGIONE
PIEMONTE

Emilia-Romagna Regional Plan on arboviruses

ALBOPICTUS MANAGEMENT PLAN EMILIA-ROMAGNA

- 1. Public health risk assessment
- 2. Monitoring by ovitraps
- 3. Standard control measures in public areas
- 4. Quality control on larvicide treatments in public road drains
- 5. Emergence control measures in case of DEN, CHIK & ZIKA imported cases detection
- 6. Community participation
- 7. Door-to-door control measures in private areas
- 8. Resistance prevention

Imported & autochthonous
Dengue, Chikungunya, Zika cases in Emilia-Romagna



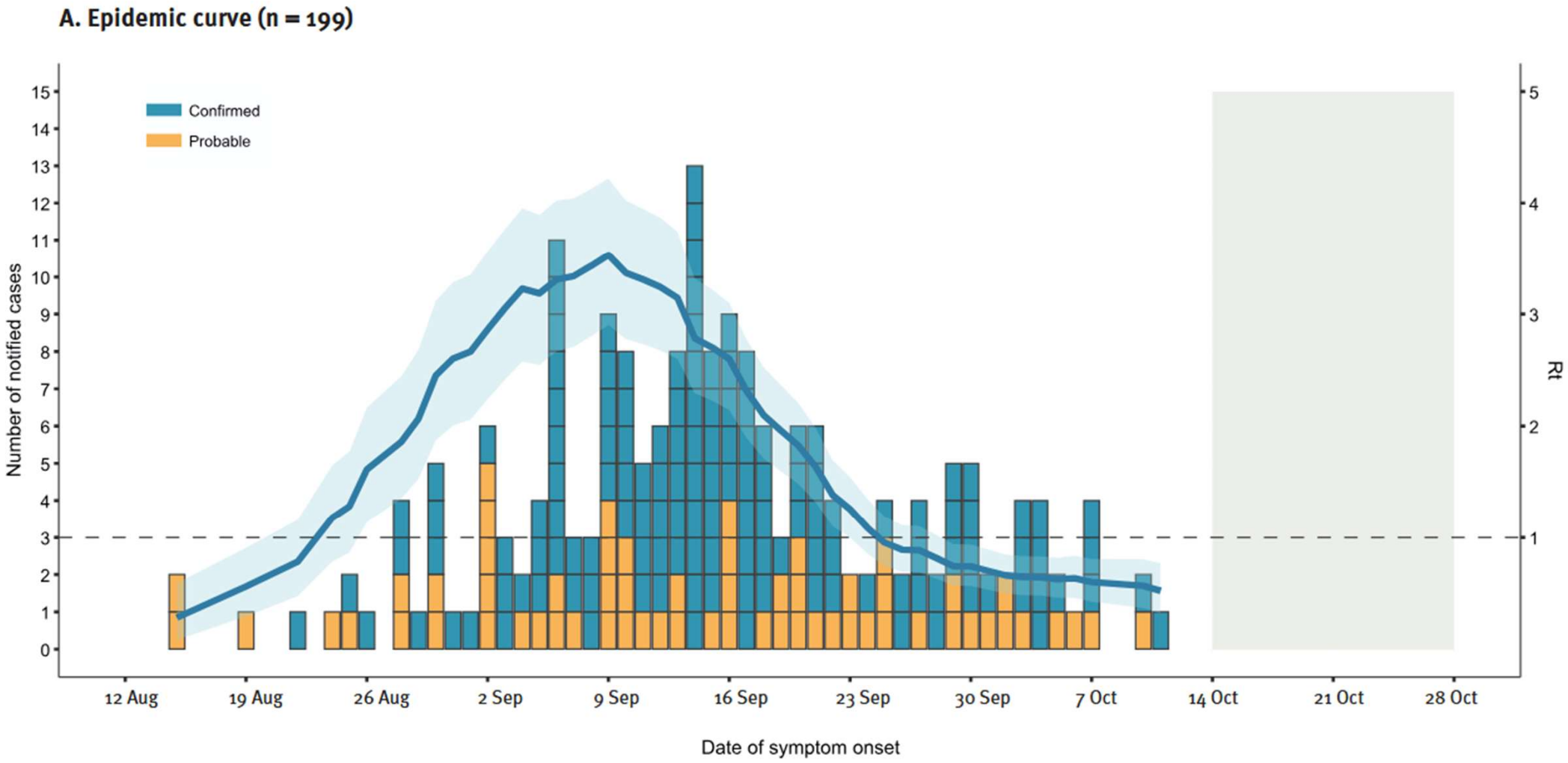
IMMEDIATE REACTION IN CASE OF IMPORTED CASES DETECTION
CHIK / DENGUE / ZIKA

- immediate adulticide treatment in public areas (for three consecutive nights)

- immediate door-to-door larvicide, adulticide and source removal

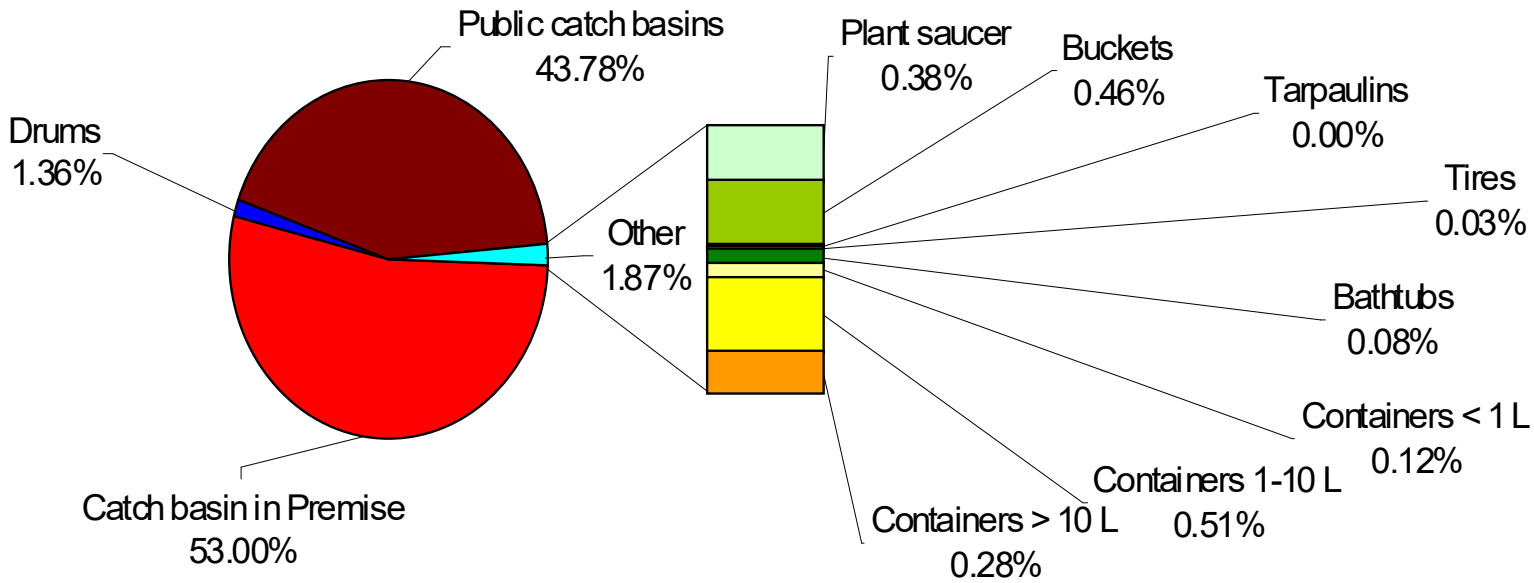
- area of 100-200 m ray

Autochthonous dengue outbreak in Marche Region, Central Italy, August to October 2024



Euro Surveill. 2024; 29(47):pii=2400713

Premises Demographic Survey (PDS)



Container typology	No. containers /premise	No. positive containers /premise	No. pupae/ha
Private Catch basin	2.35 ± 2.96	0.33 ± 0.96	237.7 ± 152.46
Plant saucer	5.79 ± 11.75	0.08 ± 0.57	1.72 ± 1.67
Drums	0.09 ± 0.62	0.03 ± 0.27	6.09 ± 11.13
Buckets	0.31 ± 1.16	0.03 ± 0.27	2.08 ± 2.35
Tarpaulins	0.09 ± 1.06	0.00 ± 0.03	0.01 ± 0.05
Tires	0.23 ± 9.75	0.00 ± 0.11	0.13 ± 0.44
Bathtubs	0.02 ± 0.23	0.00 ± 0.05	0.36 ± 0.87
Containers < 1 L	0.28 ± 3.01	0.02 ± 0.20	0.54 ± 0.64
Containers 1-10 L	0.29 ± 1.07	0.03 ± 0.27	2.28 ± 4.80
Containers > 10 L	0.09 ± 0.66	0.01 ± 0.14	1.25 ± 1.89
Public catch basins			196.4 ± 446.73

STANDARD CONTROL MEASURES IN PUBLIC AREAS

- Regular larval control in public drains (1.3 MIO)

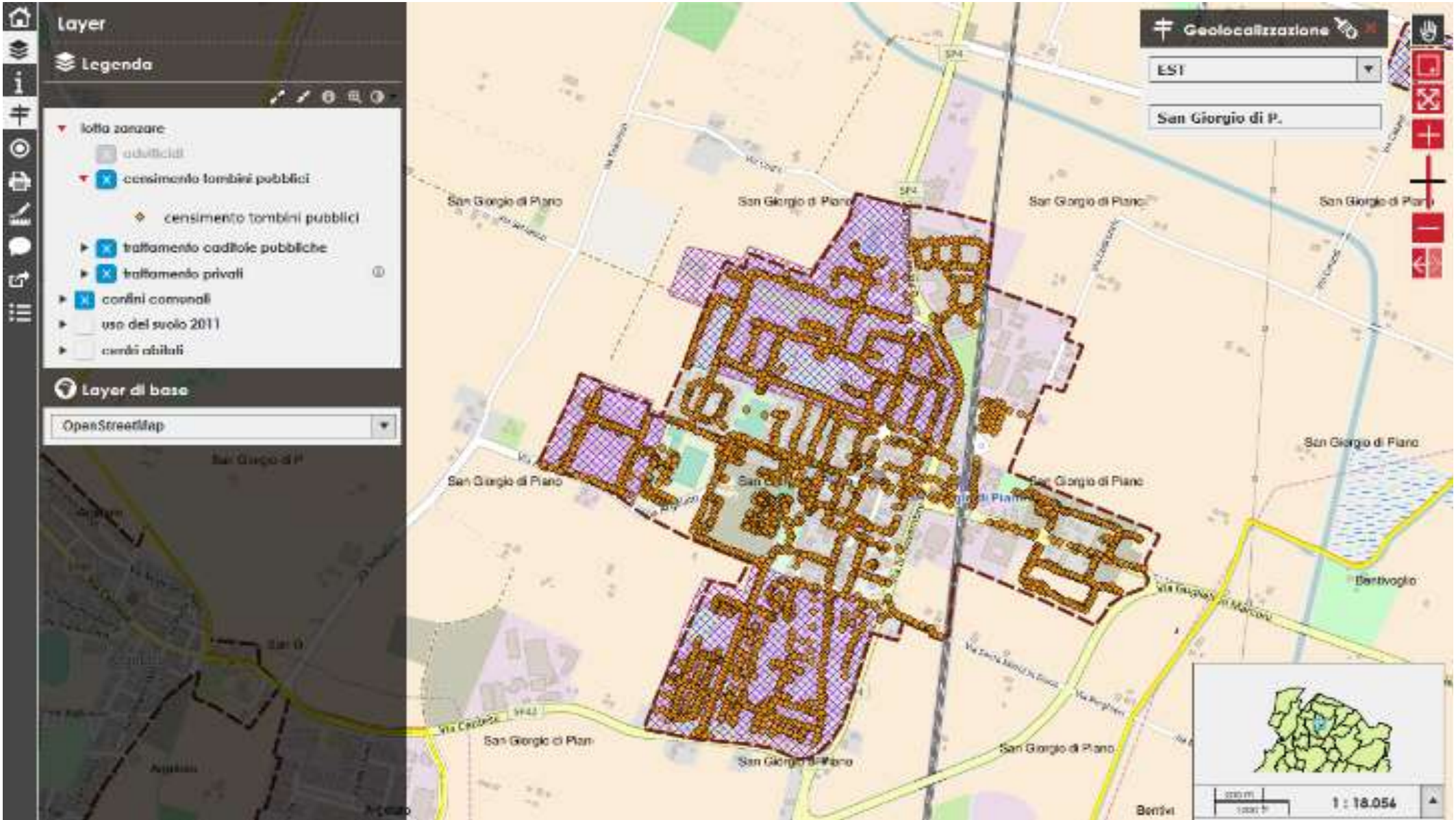
- Mayor's ordinance
- Community engagement

- Adult control in specific sites

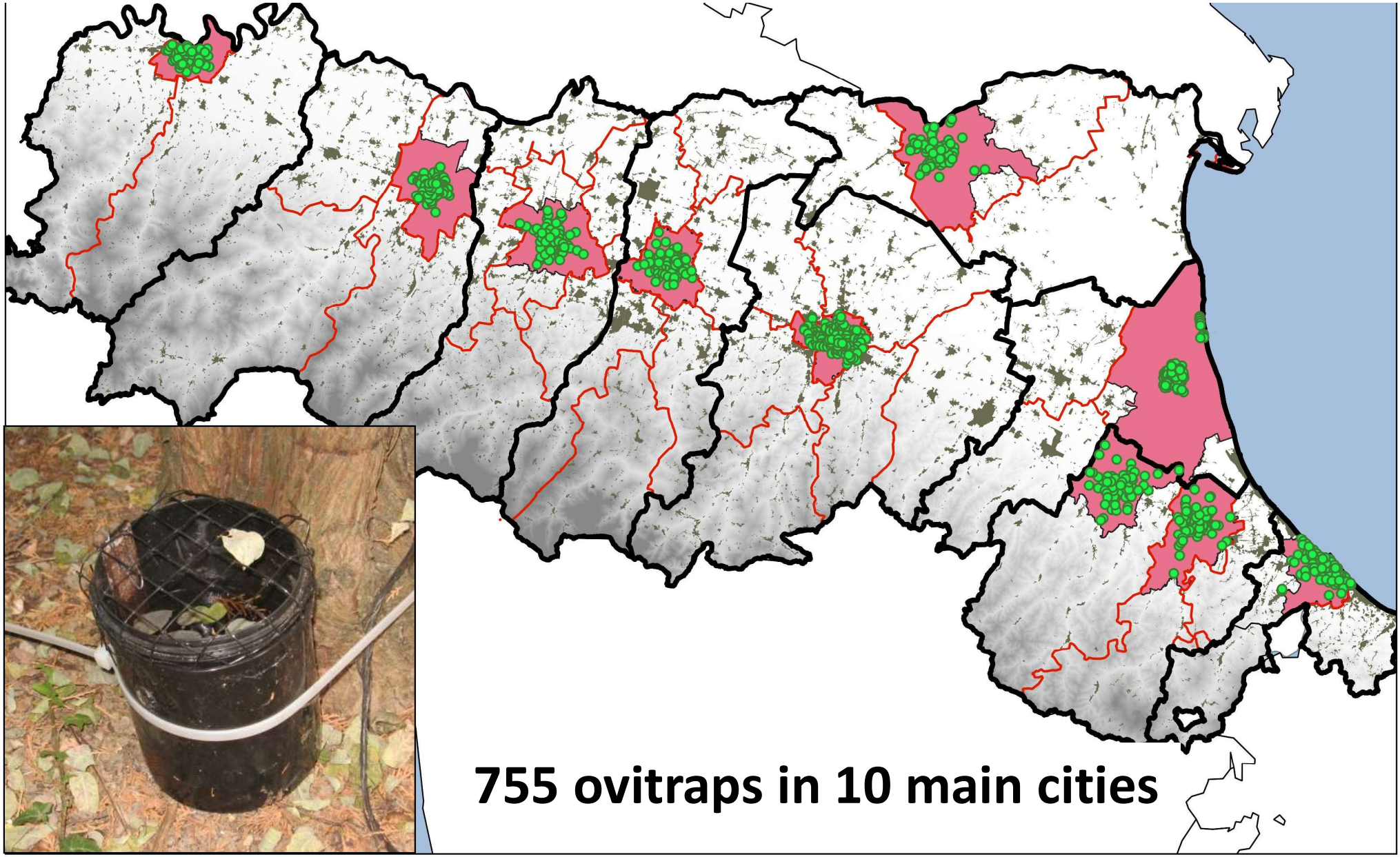
ALBO MANAGEMENT PLAN

MOSQUITO CONTROL IN PUBLIC ROAD DRAINS

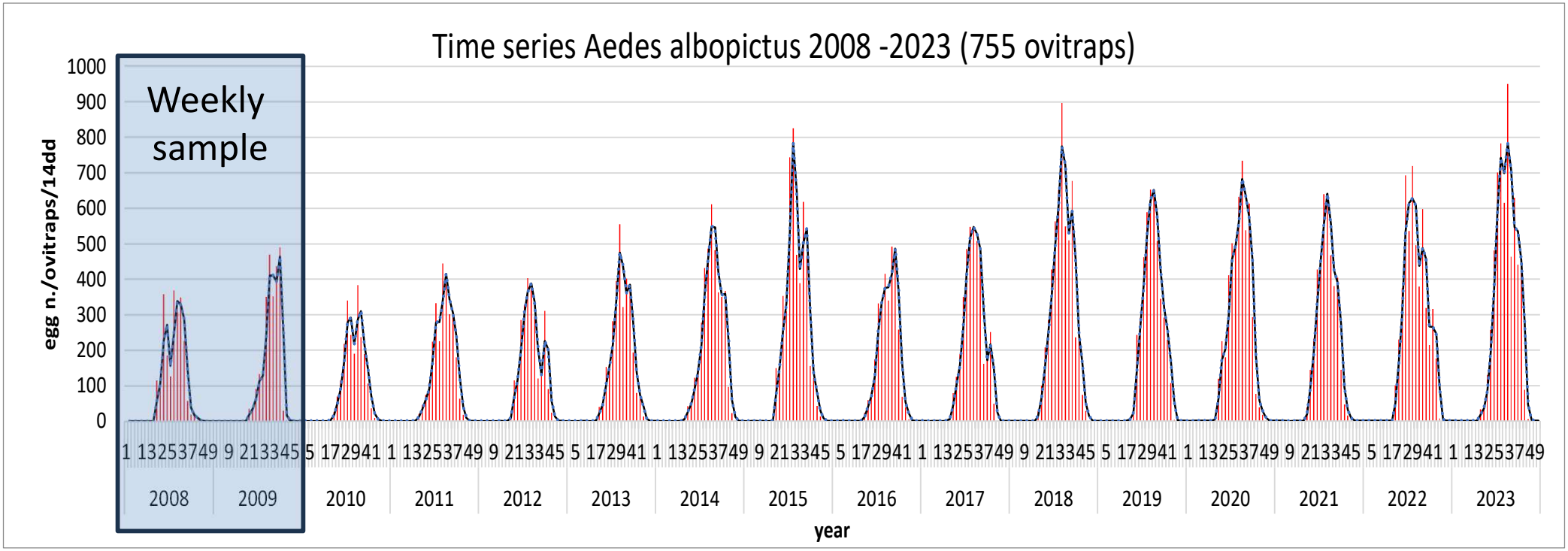
- census and mapping of public road drains



Quantitative monitoring of *Aedes albopictus*
Emilia-Romagna (4.45 ML residents)
http://www.zanzaratigreonline.it/

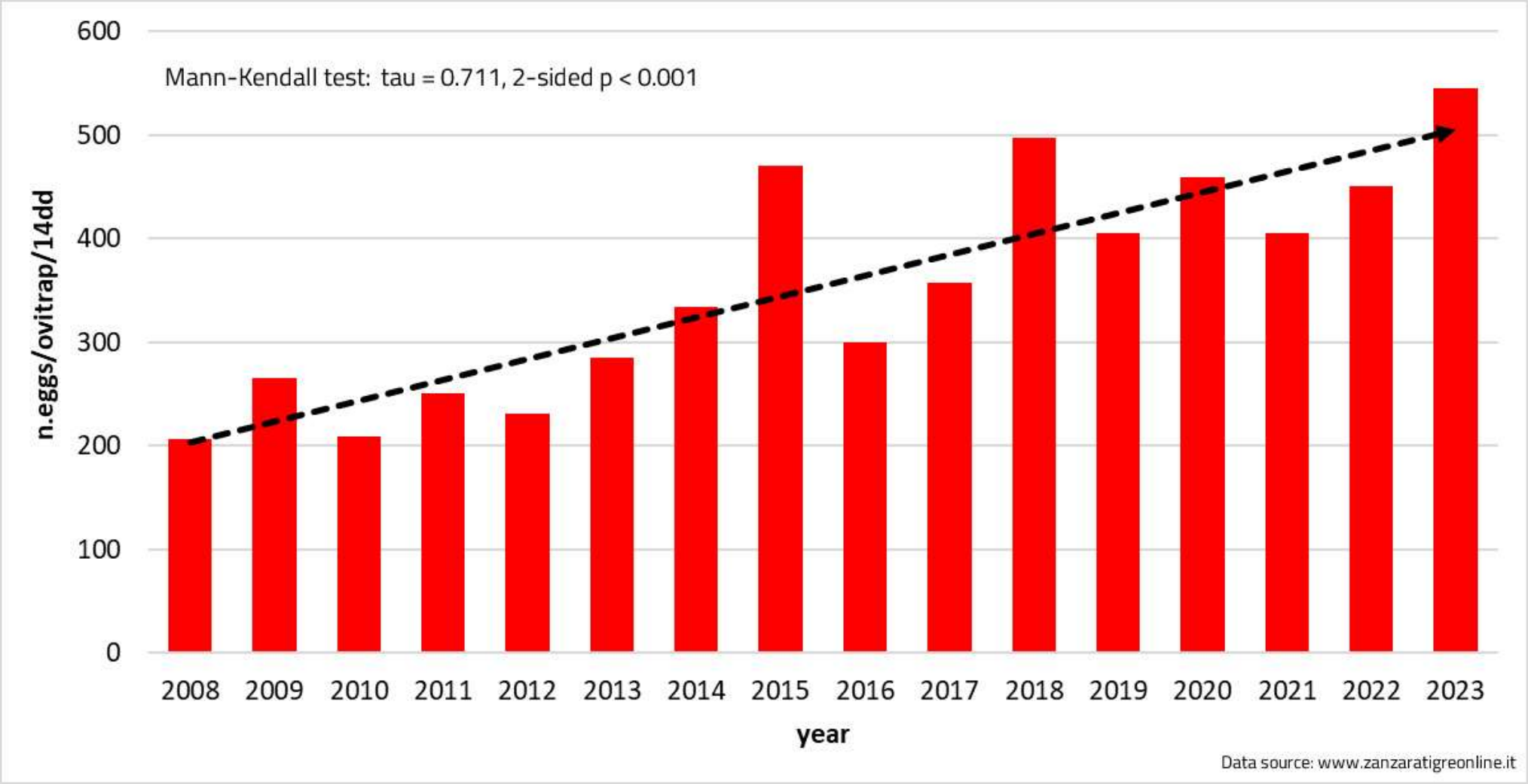


Emilia-Romagna Aedes albopictus egg monitoring



Data source: www.zanzaratigreonline.it

Emilia-Romagna Aedes albopictus egg monitoring



Epidemiological equation for VBD

No. bites/person/ day

Vector competence

Extrinsic cycle span

$$R_0 = \frac{ma^2 * V * P^n}{-\log_e P}$$

Vector longevity

Log longevity

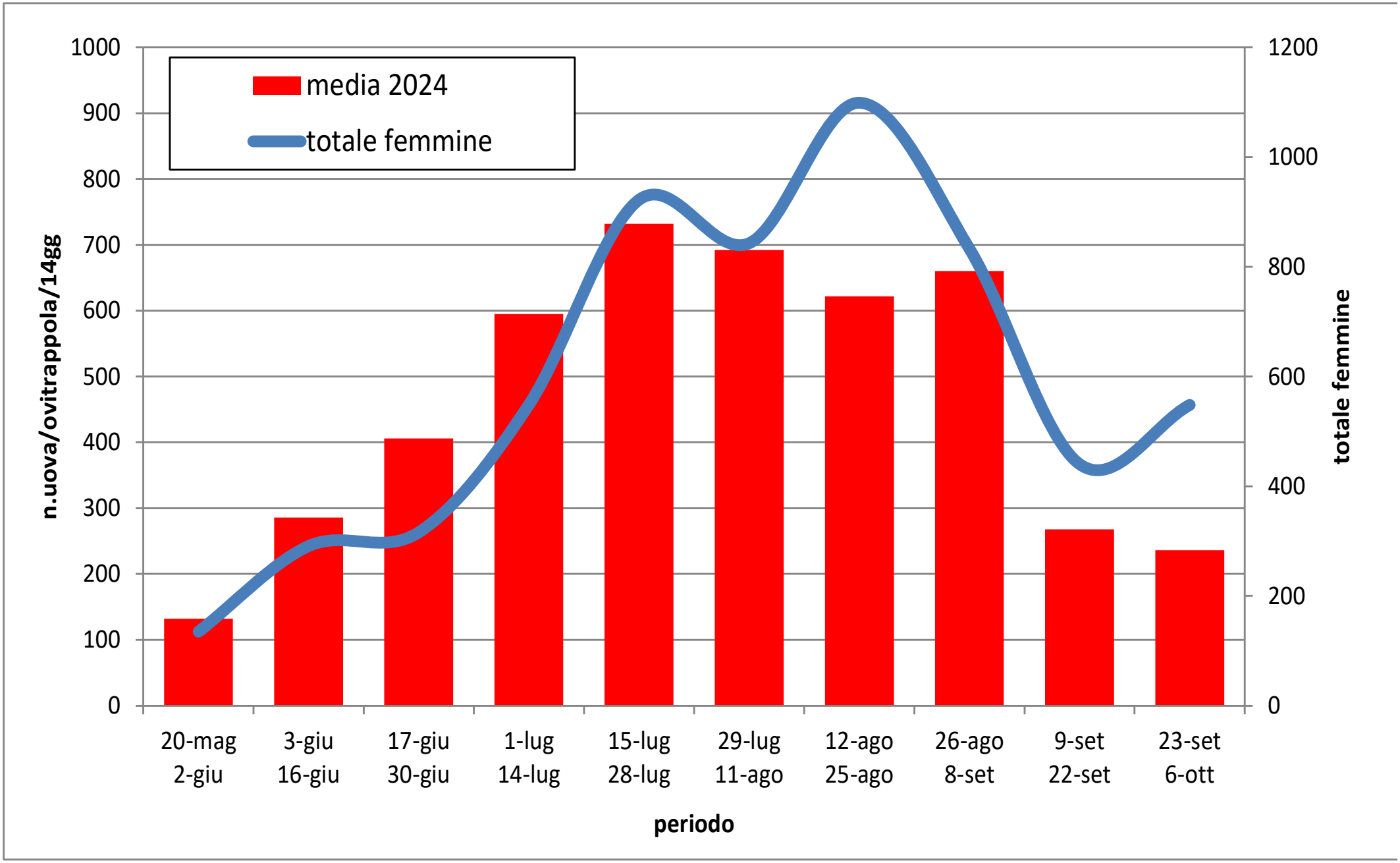
from Fine 1981 & Reisen 1989

Centro Agricoltura Ambiente Giorgio Nicoli

Aedes albopictus VBD risk estimation

No. eggs/14 days	CHIK A226V	CHIK	DEN	ZIKA
< 100	$R_0<1$	$R_0<1$	$R_0<1$	$R_0<1$
101-250	$1<R_0<2$	$R_0<1$	$R_0<1$	$1<R_0<2$
251-400	$2<R_0<3$	$R_0<1$	$R_0<1$	$1<R_0<2$
401-700	$3<R_0<5$	$1<R_0<2$	$1<R_0<2$	$2<R_0<3$
701-1000	$5<R_0<7$	$1<R_0<2$	$1<R_0<2$	$3<R_0<5$
1001-1500	$7<R_0<10$	$2<R_0<3$	$2<R_0<3$	$3<R_0<5$
> 1501	$R_0>10$	$3<R_0<5$	$3<R_0<5$	$5<R_0<7$

Aedes albopictus monitoring data
Emilia-Romagna 2024

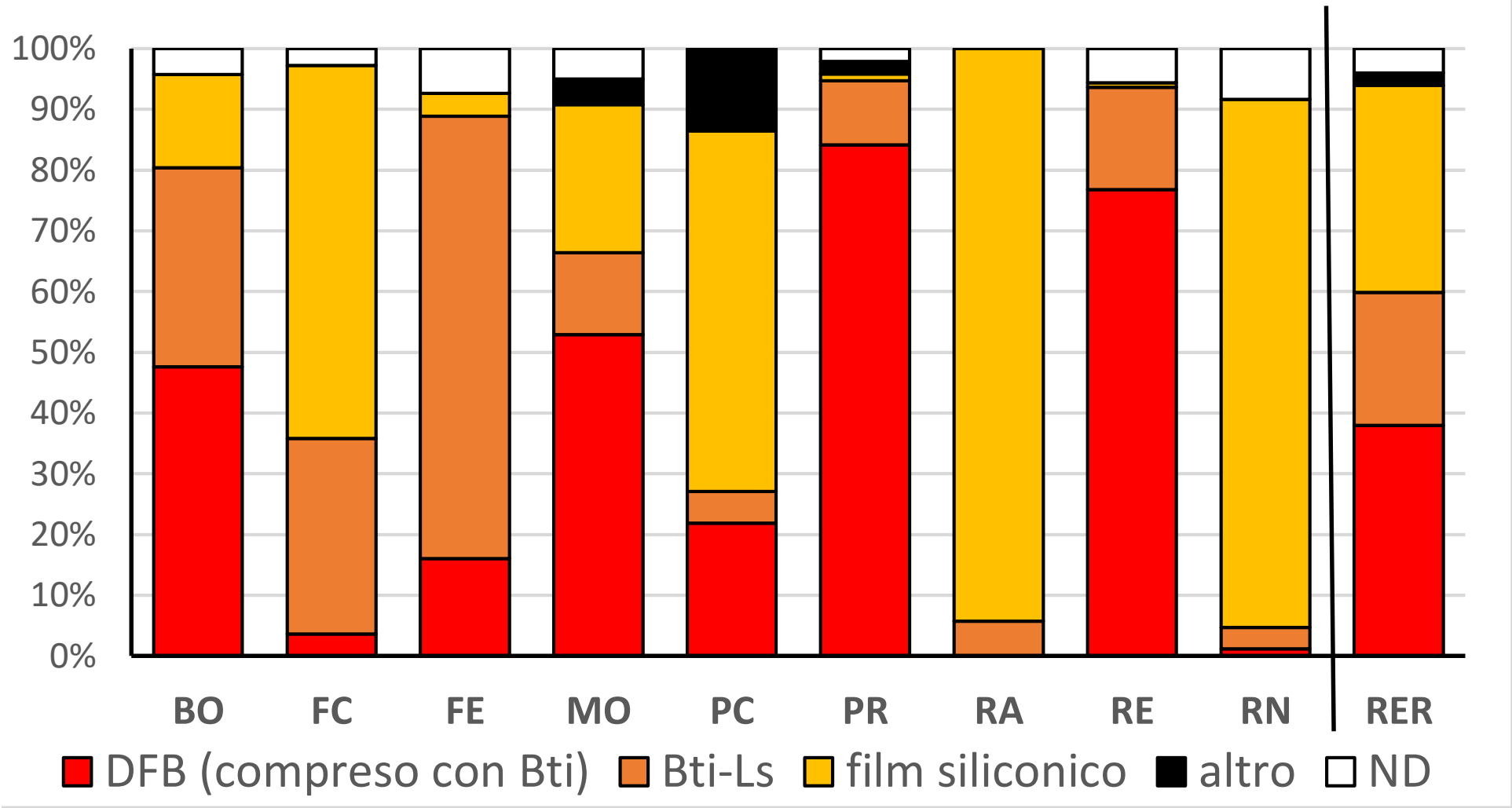


ALBO MANAGEMENT PLAN

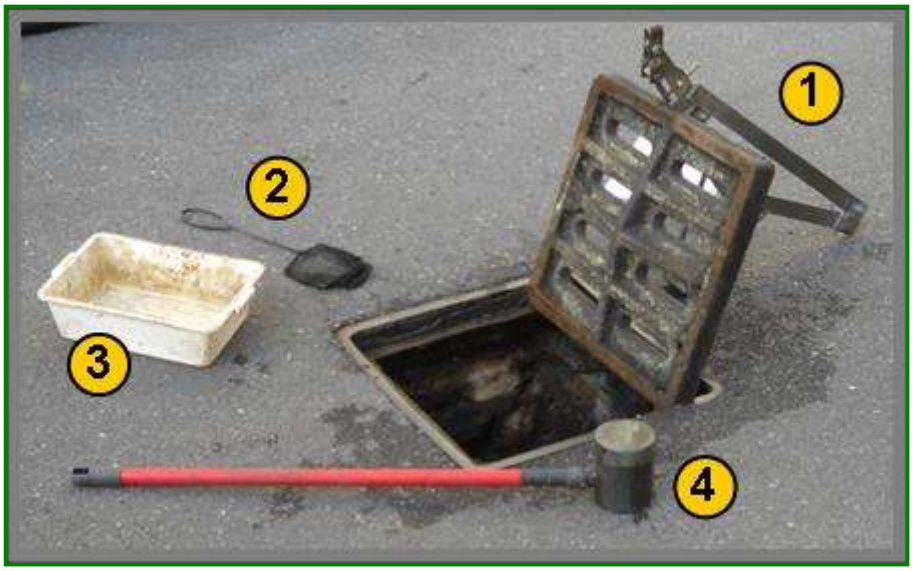
Quality control methods on larval treatments in public road drains

- Census and mapping of the public road drains
- PCO/operators must report daily on the treated roads
- Check by GPS tracking system the coverage
- 0.8-1.0 % of the total road drains censed sampled following each treatment
- In small localities a minimum number of 20 road drains must be sampled following each treatment
- Sampling conducted in a pre-defined time window (e.g. 7-14 days post-treatment) with a water net and number of larvae/pupae by species recorded
- Immediate reporting to the Municipality for penalties application

Larvicidal products utilized in public drains treatments in E-R region - 2024



Quality control standard procedure in road drain larval treatment



Opening **Sampling** **Cleaning** **Counting**

EMILIA-ROMAGNA REGIONAL PLAN

Quality control in road drain larval treatment

	2020			2021			2022			2023			2024		
	N. CHECK	% POS AEDES	% POS CULEX	N. CHECK	% POS AEDES	% POS CULEX	N. CHECK	% POS AEDES	% POS CULEX	N. CHECK	% POS AEDES	% POS CULEX	N. CHECK	% POS AEDES	% POS CULEX
RIMINI	2125	0.2	0.7	3292	2.1	8.3	1881	1.2	2.1	2114	1.8	1.6	1472	2.3	1.8
RICCIONE	1000	1.3	**26.5**	1000	8.8	**35.0**	1054	8.5	**24.7**	2026	1.8	**11.1**	no data		
RAVENNA	1147	1.1	0.9	1168	0.5	0.5	3233	2.5	0.7	3131	0.9	0.9	2986	2.9	0.4
FORLI'	740	1.6	5.4	727	5.8	5.8	1336	9.7	1.9	1322	2.8	2.1	1284	3.3	1.6
CESENA	508	6.1	4.3	512	7.8	1.4	1236	7.9	1.6	622	4.8	5.5	566	**10.4**	2.1
IMOLA	3870	3.2	2.6	1491	2.1	1.0	1490	1.1	1.0	1495	1.3	1.5	1484	1.8	1.7
BOLOGNA	1457	4.6	3.2	5892	4.4	6.3	7099	5.5	8.9	7099	4.0	6.7	6652	4.9	7.2
FERRARA	no data			360	4.4	1.9	360	3.1	1.9	984	8.5	4.5	1109	**12.2**	
MODENA	1659	1.7	1.5	1920	4.5	1.9	3286	7.9	1.8	2494	7.5	3.9	2696	3.4	1.7
REGGIO E.	2651	3.2	2.6	2631	2.2	1.4	2768	3.7	2.4	2912	9.1	5.0	2903	6.4	1.9
PARMA	877	**23.6**	**11.1**	709	9.0	8.2	1107	4.2	**11.7**	766	15.4	7.2	963	3.3	0.4
PIACENZA	no data			no data			672	9.8	6.3	0			420	**16.0**	6.0
TOTAL	16034			19702			25522			24965			22535		

ALBO MANAGEMENT PLAN

Door-to-door control measures in private areas

- Six larval control treatments in the public road drains (minimum threshold of treated road drains 95%)
- Six door-to-door interventions (larval control, source removal and citizen direct education) (minimum threshold of properties inspected 95%)
- Identification and reporting to the authorities of the non-collaborative citizen
- Introduction of Copepods in large water containers
- Info contact green point (web, phone)
- Socio-economic and environmental impact evaluation

Pilot unit for *Aedes albopictus* sterile male mass-production in Crevalcore – Bologna - Italy

Indicative cost-efficacy *Aedes albopictus* control (Northern Italy)

	€/inhab/ year	% pop reduction	Residual mean no. eggs/ovitrap/14 d
Current IMM	~ 1	~ 30-40	~ 400-600
Intensive DtD	~ 6-8	~ 50-60	~ 200-250
SIT package	~ 9-10	~ 80	~ 100-150

Phone survey on the expenses related to *Aedes albopictus* per E-R family/year

Product	% (N=412)	Cost (€)	N
Insecticide aerosol (domestic)	32.08	**6.10**	132
Electrical vaporizers	37.86	**4.40**	156
Outdoor repellents	42.58	**4.07**	175
Skin repellents	62.53	**7.50**	257
Mosquito traps	9.95	**39.96**	41
Larvicides	45.73	**3.72**	182
Others	1.46	**46.29**	6
Adulticides	9.71	**10.75**	40
After bite product	3.88	**6.10**	16

LIFE Conops project 2013-2018
Laura Vici, Stefano Rivas Morales & Massimo Canali
Dept. of Statistics / Dept. of Food and Agricultural Sciences, University of Bologna

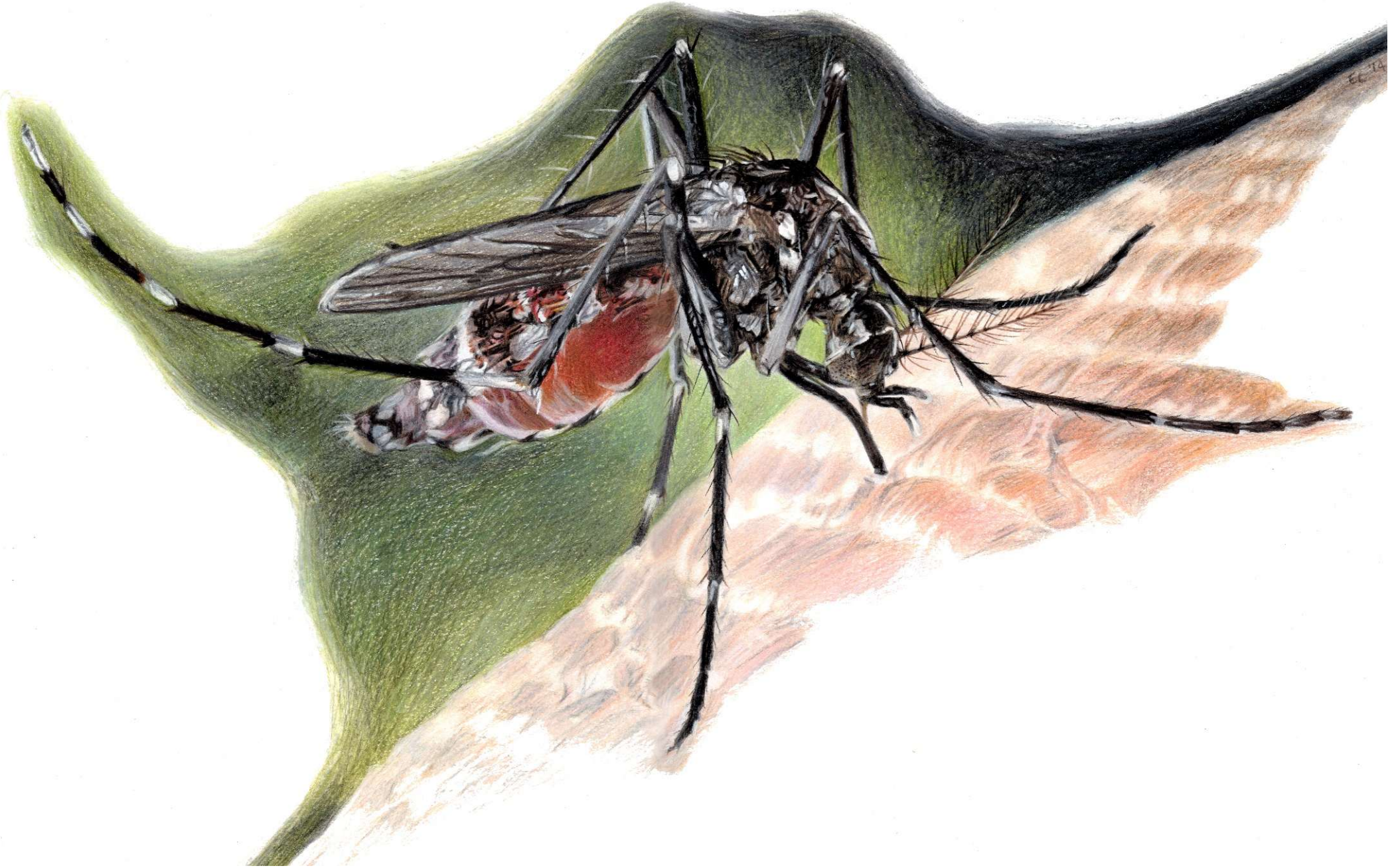
Median annual expense per family

2.4 anti-mosquito products

26.16 – 48.11 Euro

Laura Vici, Stefano Rivas Morales & Massimo Canali
Dept. of Statistics / Dept. of Food and Agricultural Sciences, University of Bologna

Any questions or comments ?



Overview du contrôle de la transmission des arboviroses liées à Aedes

Protéger les communautés avec Wolbachia - Indonésie

par Edwige Rancès

Protéger les communautés avec *Wolbachia*

INDONÉSIE

Edwige Rancès

World Mosquito Program™ | MONASH University

Qui sommes nous?

Organisation à but non lucratif appartenant à l'Université Monash, Australie.

Bureaux en Australie et en France

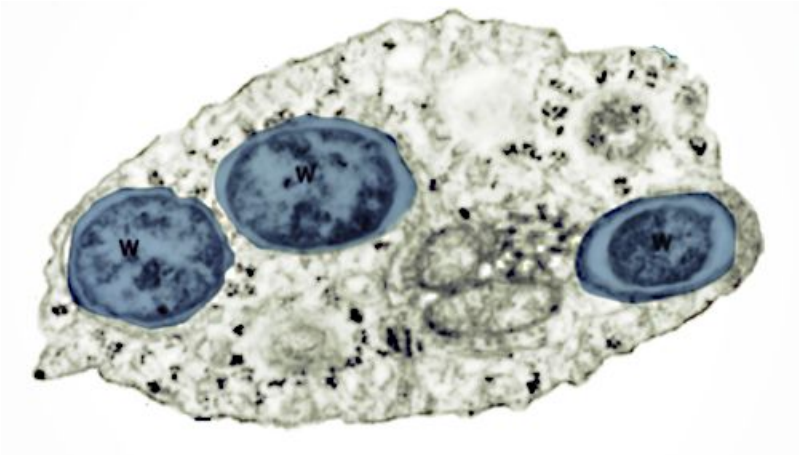
Équipe internationale et multidisciplinaire

Construisons avec les gouvernements

Des partenariats stratégiques fondés sur la co-création et l'intégration à long terme.

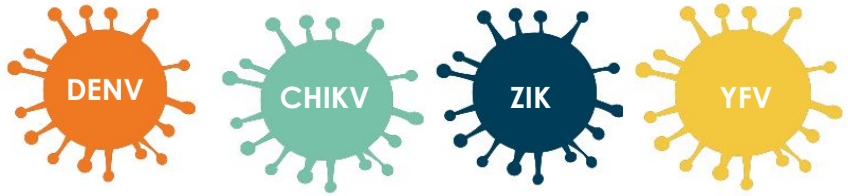
C'est ainsi que nous protégeons davantage de personnes, de manière plus durable.

Wolbachia dans une cellule d'insecte

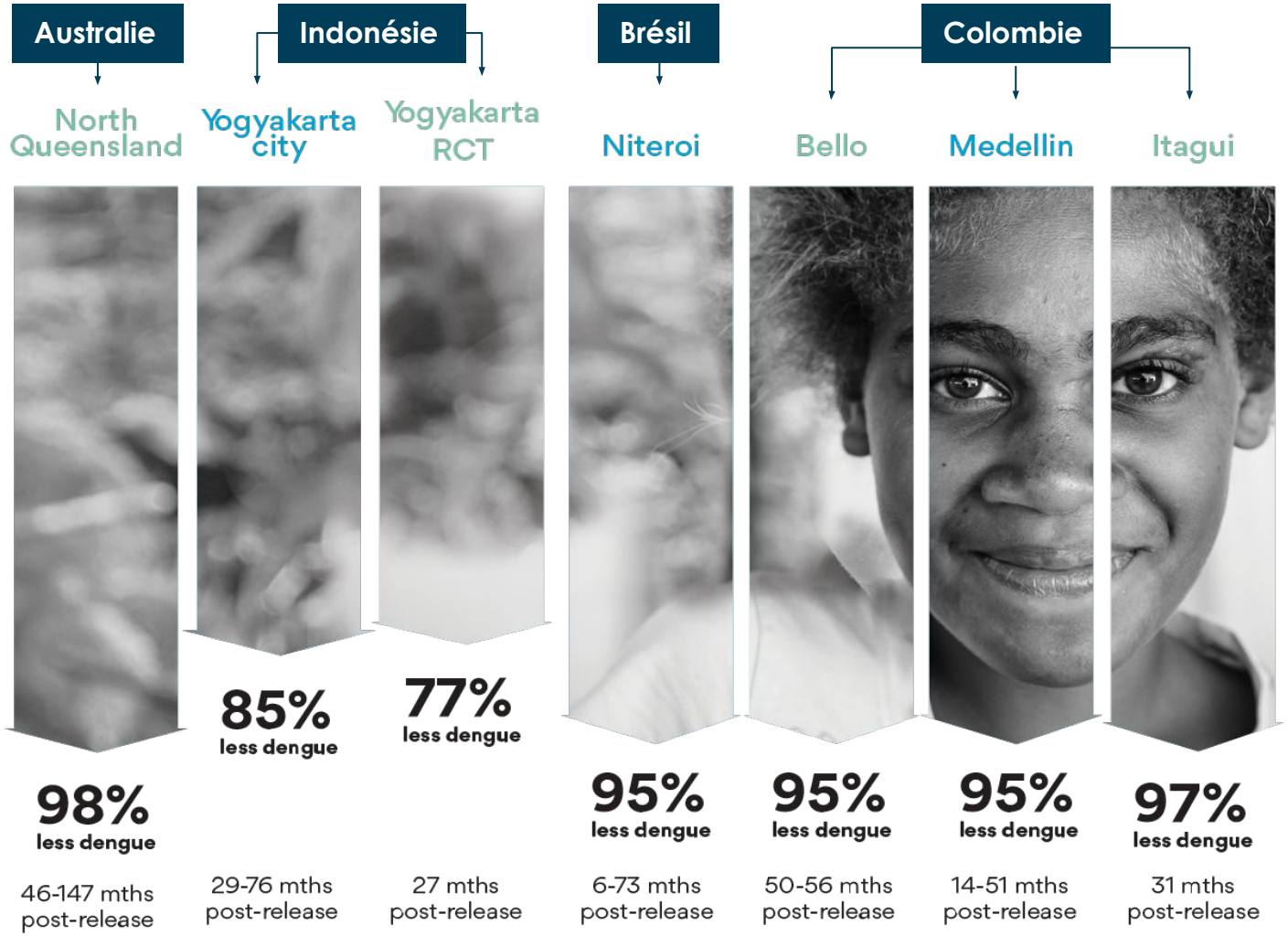


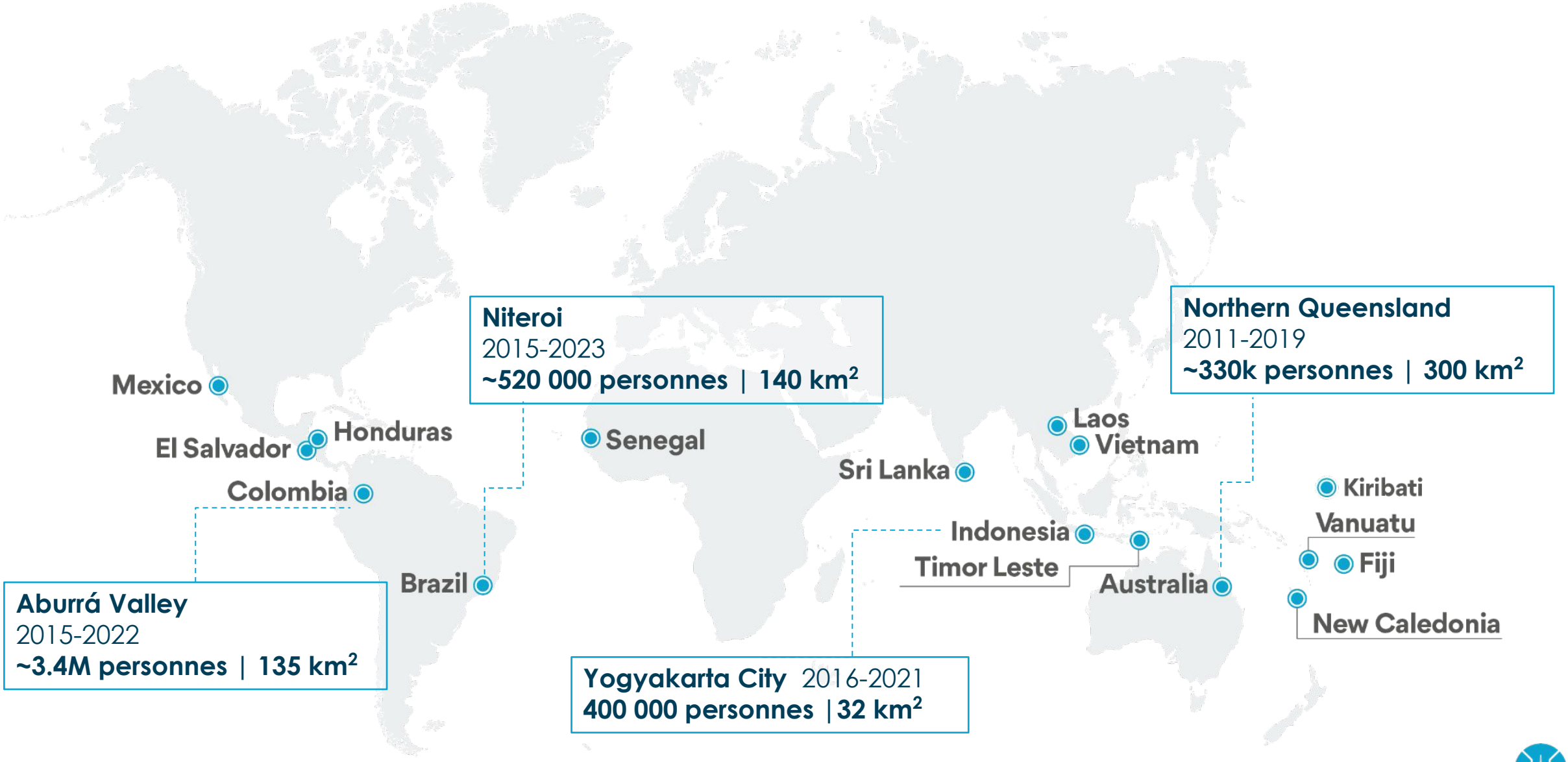
Plus de 50% des populations d'insectes portent *Wolbachia*

- ***Wolbachia*, outil de lutte biologique contre :**



Réduction de l'incidence de la dengue après l'introgression de *Wolbachia* dans les populations naturelles d'*Aedes aegypti* : essai randomisé, séries chronologiques.




Mexico
El Salvador
Honduras
Colombia
Brazil
Senegal
Sri Lanka
Laos
Vietnam
Indonesia
Timor Leste
Australia
Kiribati
Vanuatu
Fiji
New Caledonia
Niteroi
2015-2023
~520 000 personnes | 140 km²
Northern Queensland
2011-2019
~330k personnes | 300 km²
Aburrá Valley
2015-2022
~3.4M personnes | 135 km²
Yogyakarta City 2016-2021
400 000 personnes | 32 km²

Les résultats des analyses socio-économiques (coût/efficacité) prédisent *Wolbachia* comme étant une solution efficiente.

En moyenne, chaque BRL investi **devrait rapporter 278,73 BRL en bénéfices économiques**.
Zimmermann et al., 2024 The Lancet Regional Health Americas

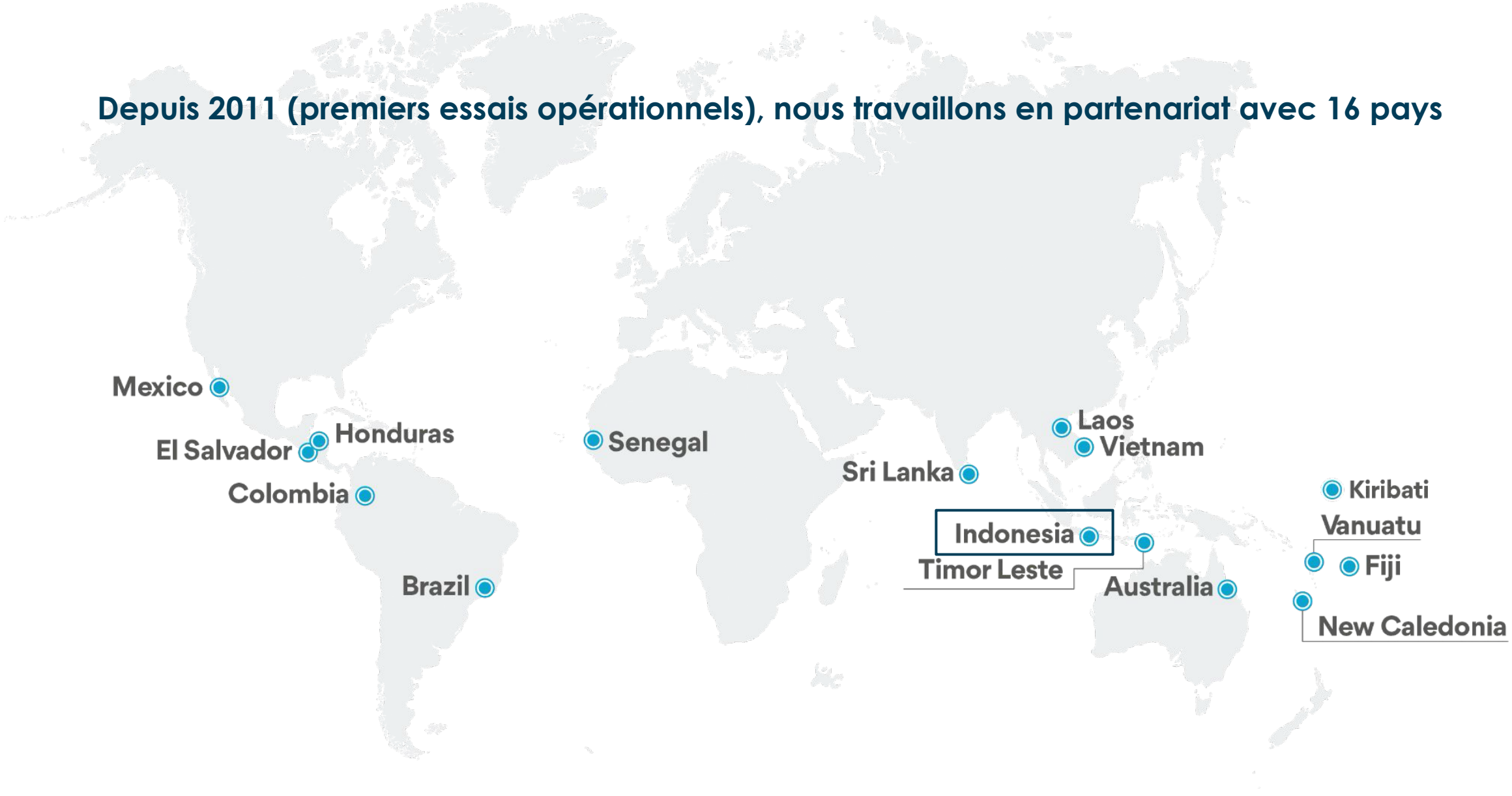
En moyenne, chaque dollar investi **devrait rapporter 1,69 $ en bénéfices économiques sur 20 ans**
Turner HC, et al. PLoS Negl Trop Dis 2023.

Les avantages économiques sur 10 ans dépassent 5,00 $ US pour chaque dollar investi
Shepard et al;, 2025

Rembourse 2 à 3 fois l'investissement sur 10 ans grâce aux économies réalisées sur les frais médicaux et la perte de productivité
Brady OJ, et al. BMC Medicine 2020.

Une seule épidémie de dengue (coût de santé et mesure de lutte antivectorielle) coûte 2 fois l'investissement réalisé.
Une épidémie de dengue a coûté 13 millions d'euros.
Une intervention *Wolbachia* a coûté 6,5 millions d'euros.
DASS New Caledonia Government.

Depuis 2011 (premiers essais opérationnels), nous travaillons en partenariat avec 16 pays

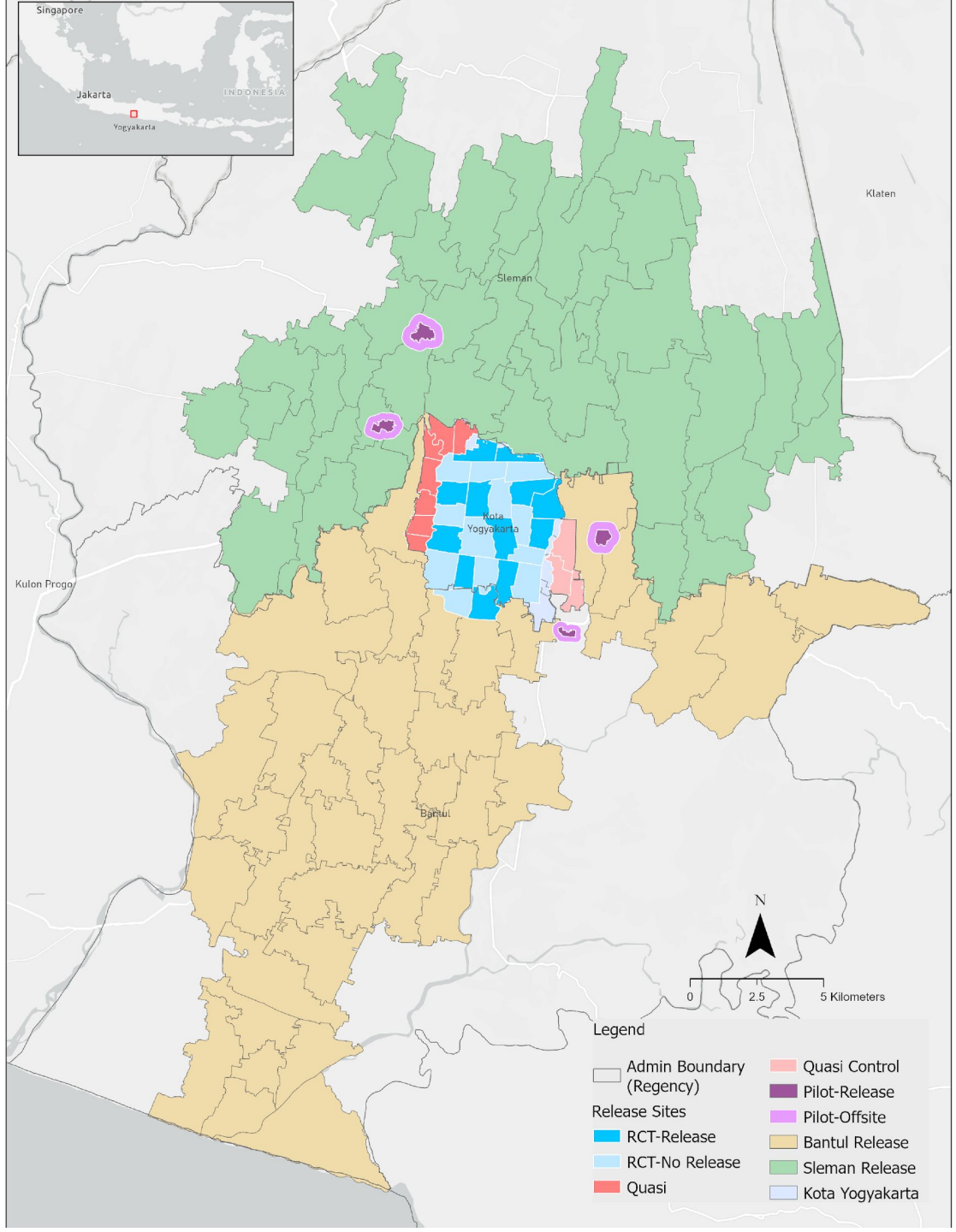


Yogyakarta Special Region

543km2 **1.8 million de personnes protégées**

World Mosquito Program

UNIVERSITAS GADJAH MADA



2014-2015 Pilotes périurbains

2016-2019 **Étude quasi-expérimentale (2006-2019)**
Déploiement de *Wolbachia* dans la zone expérimentale (2016)

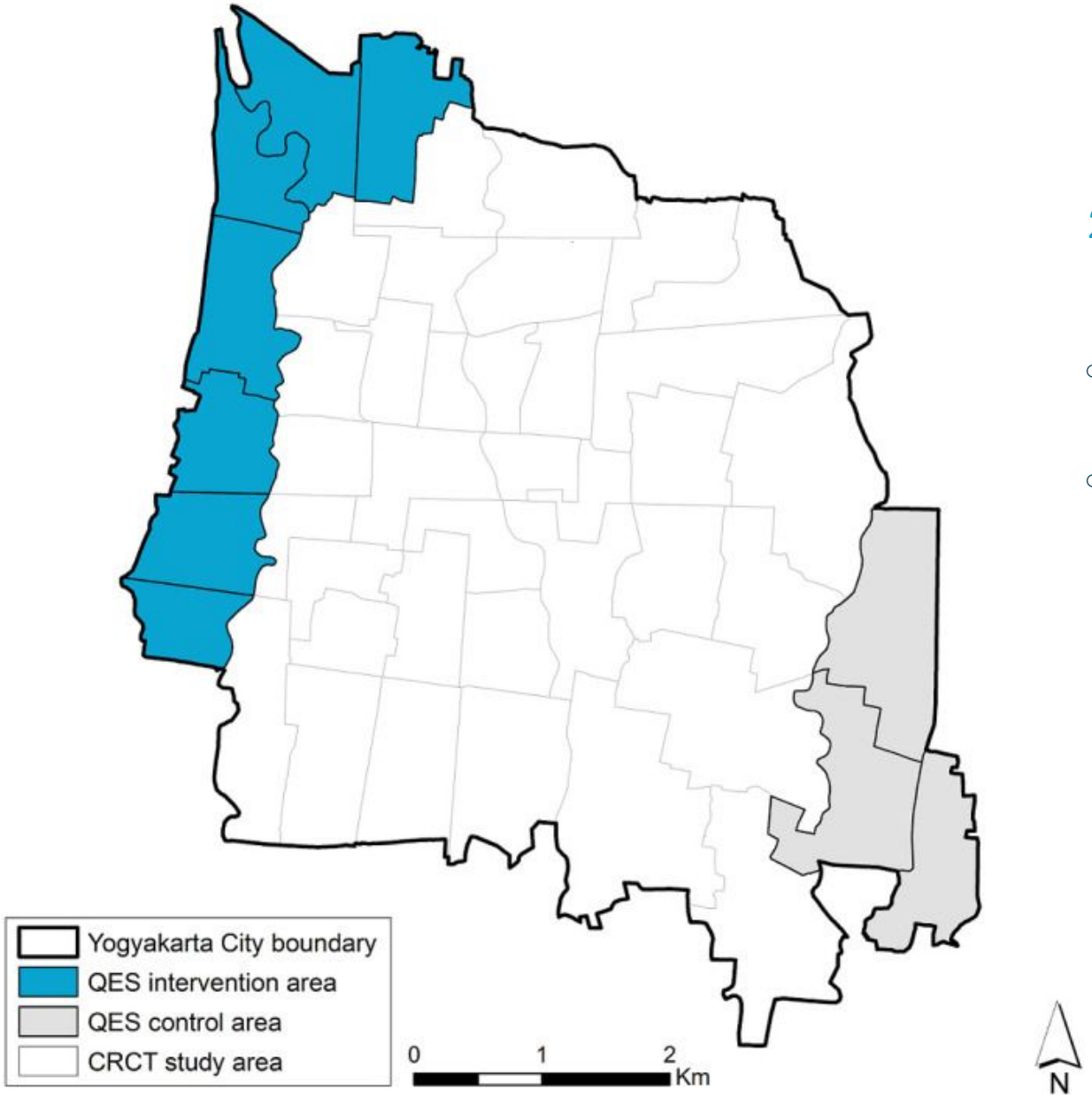
2017-2020 **Essai clinique randomisé par grappes**
Déploiement de *Wolbachia* dans les clusters expérimentaux (2017)

2020-2021 Déploiement de *Wolbachia* dans les zones/clusters témoins

2021-2022 Déploiement de *Wolbachia* dans la province de Sleman

2022-2023 Déploiement de *Wolbachia* dans la province de Bantul

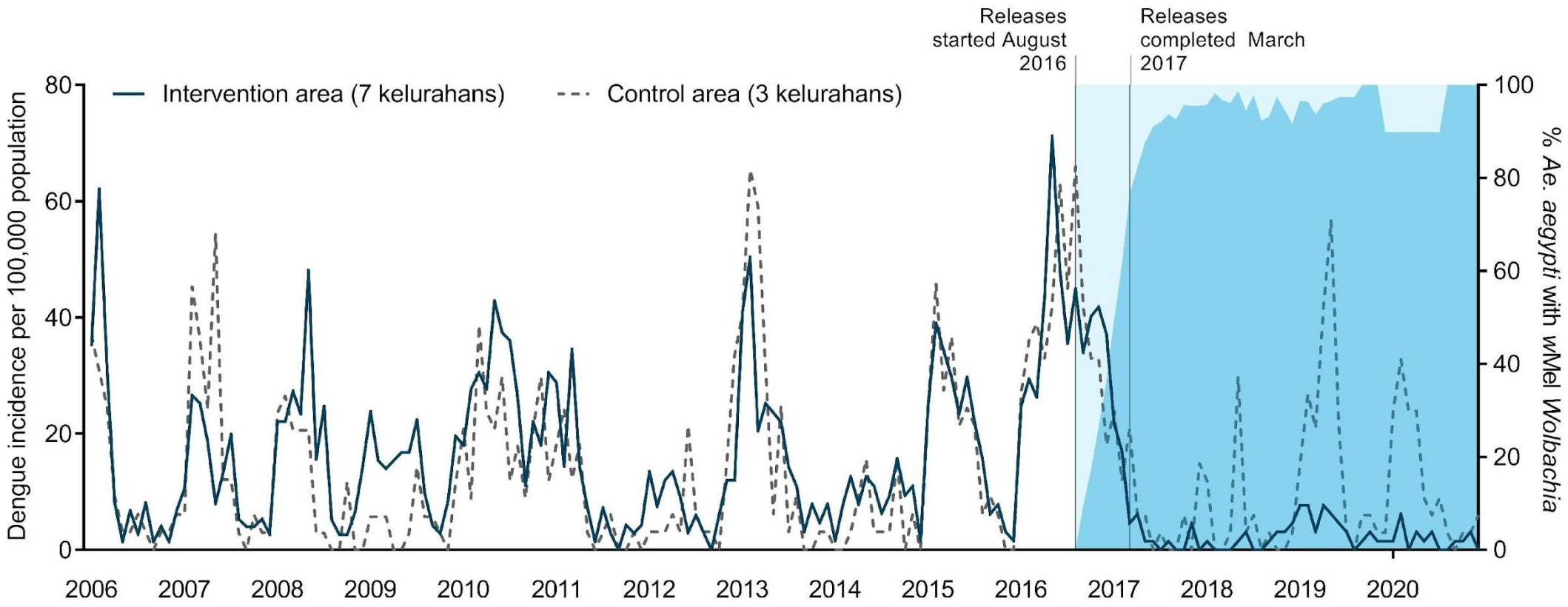
2023-2025 **Étude au long terme post-intervention**



2016-2019 Étude quasi-expérimentale

- *Objectif principal :* Évaluer l'impact du déploiement de *Wolbachia* sur l'incidence de la dengue.
- *Intervention :* Introgression de *Wolbachia* dans les populations d'*Aedes aegypti* (Aout 2016 – Mars 2017)
  - Zone intervention : 65 000 habitants, 4,9 km^2
  - Zone témoin : 34 000 habitants, 3.1 km^2

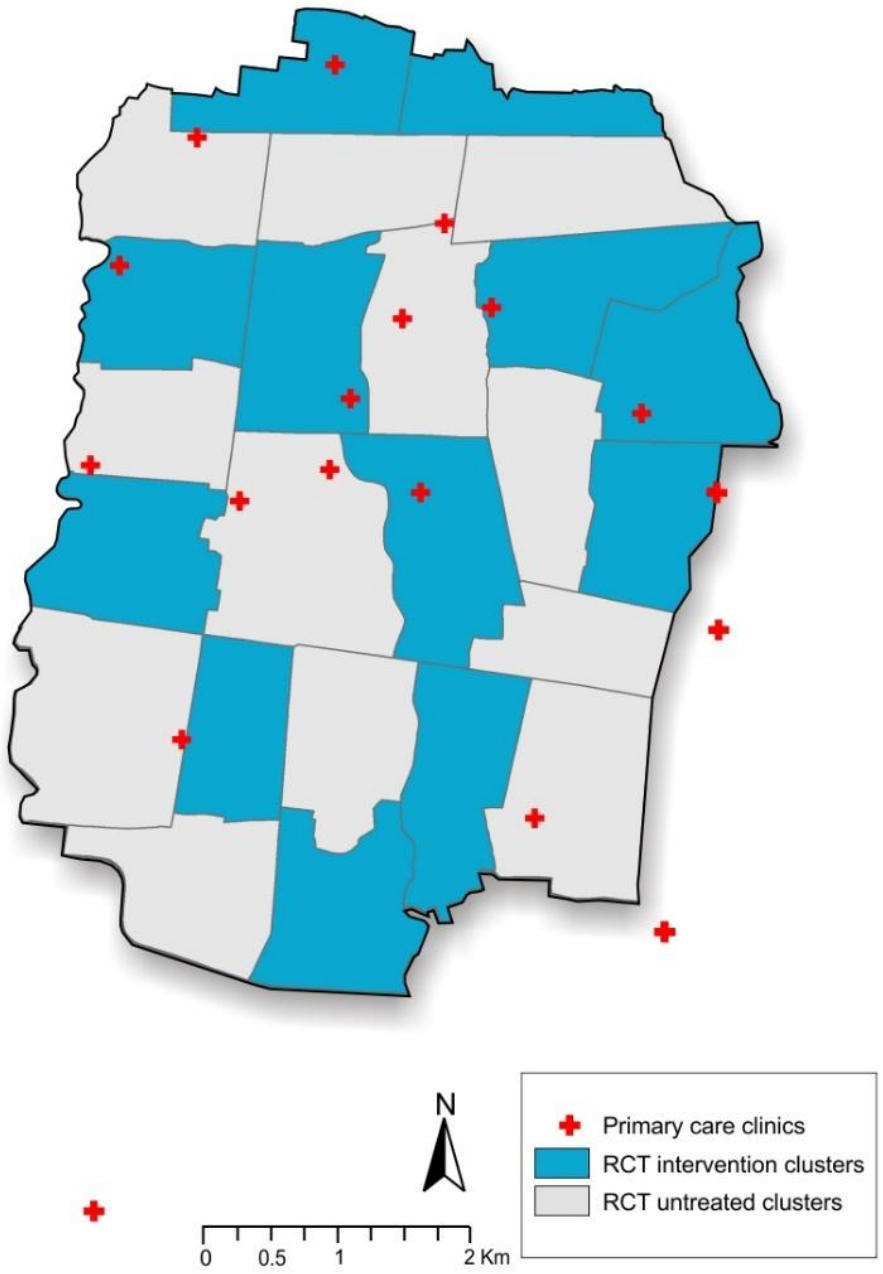
Indriani *et al.*, 2020



76% réduction (95% CI: 60%, 86%) de l'incidence de la dengue

Étude de séries chronologiques de cas de dengue notifiés (2006-2019)

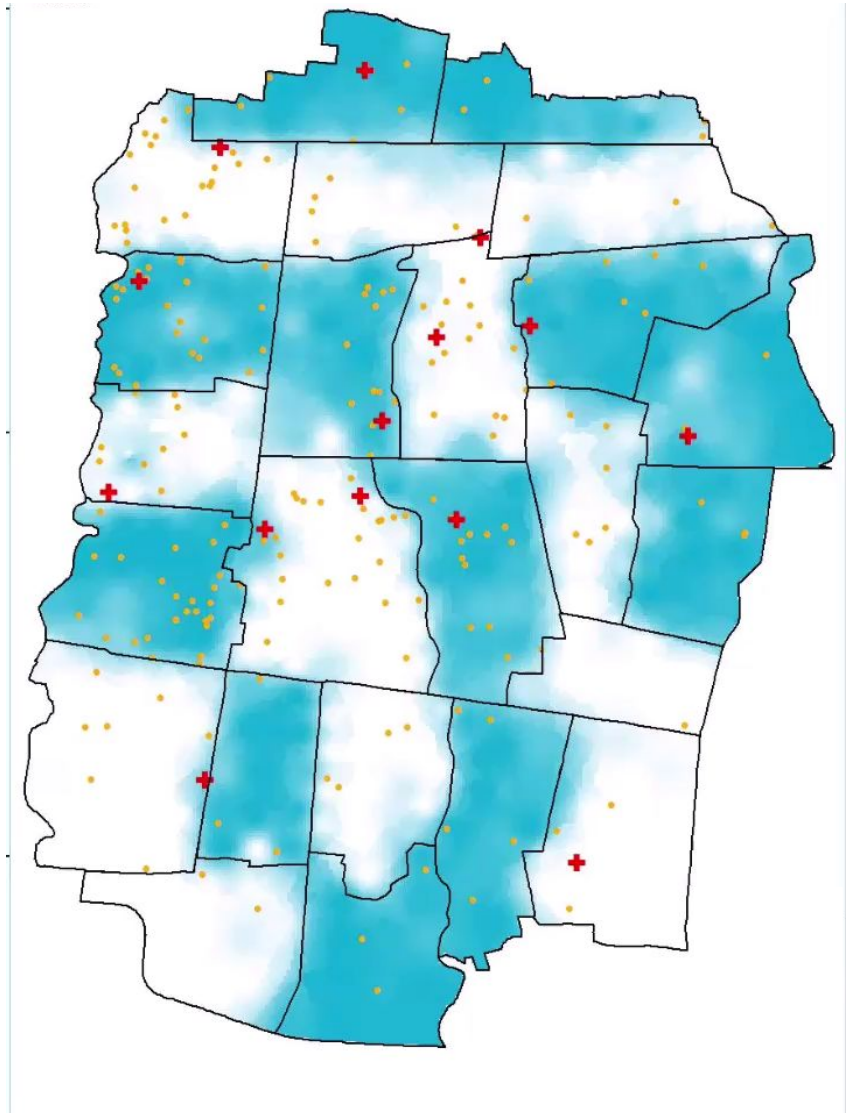
Indriani *et al.*, 2020



2016-2020 Étude expérimentale

- Essai clinique randomisé par grappes (clusters)
- *Objectif principal :* Évaluer l'efficacité du déploiement de *Wolbachia* sur la réduction de l'incidence de cas de dengue confirmés virologiquement, sur une population âgée de 3 à 45 ans.
- *Objectif secondaire :* Évaluer l'efficacité du déploiement de *Wolbachia* sur la réduction de l'incidence de cas de chikungunya et de zika confirmés virologiquement, sur une population âgée de 3 à 45 ans.
- *Intervention :* Introgression de *Wolbachia* dans les populations d'*Aedes aegypti* (Mars 2017-Décembre 2017)
  - Zone intervention : 12 clusters, approx 1 km^2
  - Zone témoin : 12 clusters, approx 1 km^2
- Nombre d'habitants : 311 700

Atarini *et al.*, 2021



100%

50%

0%

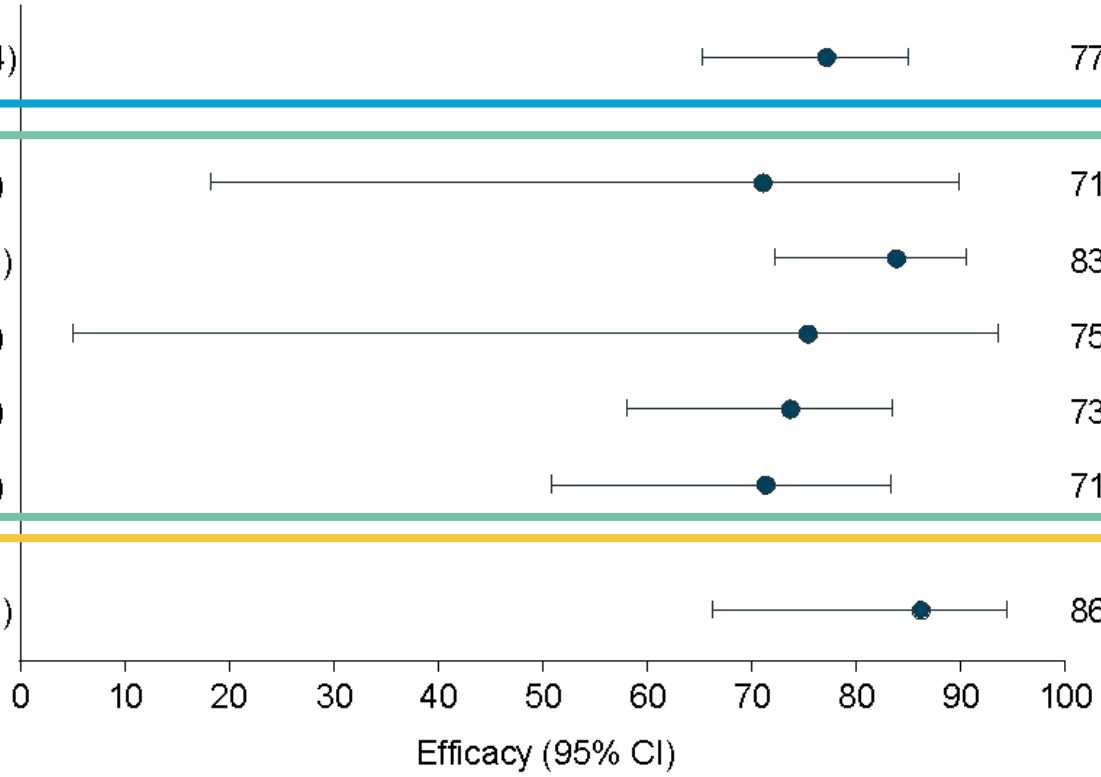
Prévalence *Wolbachia* Janvier 2018

Participants (cumulative)

Puskesmas

Atarini *et al.*, 2021

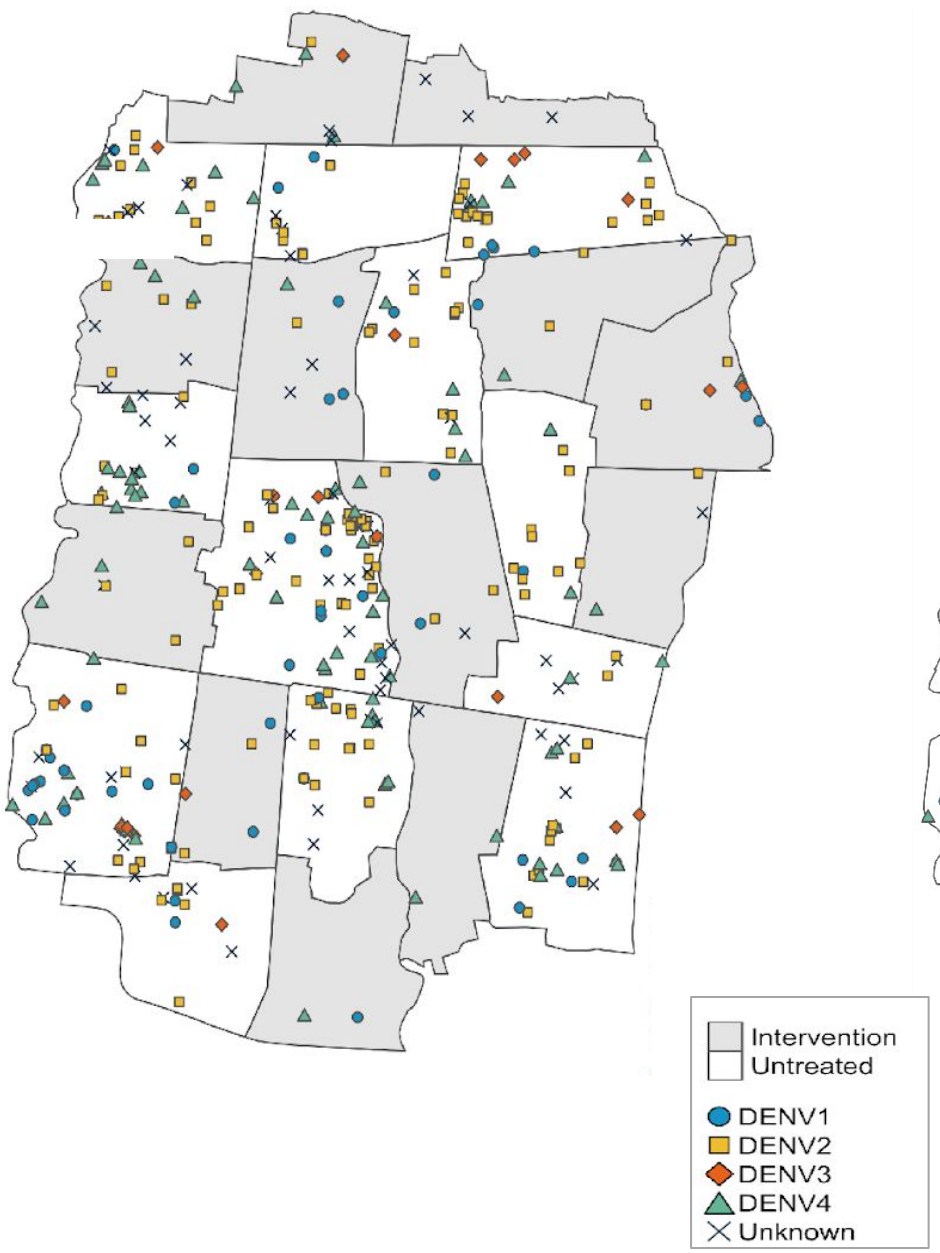
	no. of cases/total no. (%)		Efficacy (95% CI)
	Intervention	Untreated	
All VCDs	67/2,905 (2.3)	318/3,401 (9.4)	77.1 (65.3 to 84.9)
DENV1	12/2,905 (0.4)	45/3,401 (1.3)	71.0 (18.2 to 89.7)
DENV2	20/2,905 (0.7)	134/3,401 (3.9)	83.8 (72.1 to 90.6)
DENV3	5/2,905 (0.2)	22/3,401 (0.6)	75.3 (4.9 to 93.6)
DENV4	17/2,905 (0.6)	70/3,401 (2.1)	73.6 (57.9 to 83.5)
Unknown serotype	14/2,905 (0.5)	53/3,401 (1.6)	71.3 (50.8 to 83.3)
Hospitalised VCDs	13/2,905 (0.4)	102/3,401 (3.0)	86.2 (66.2 to 94.3)

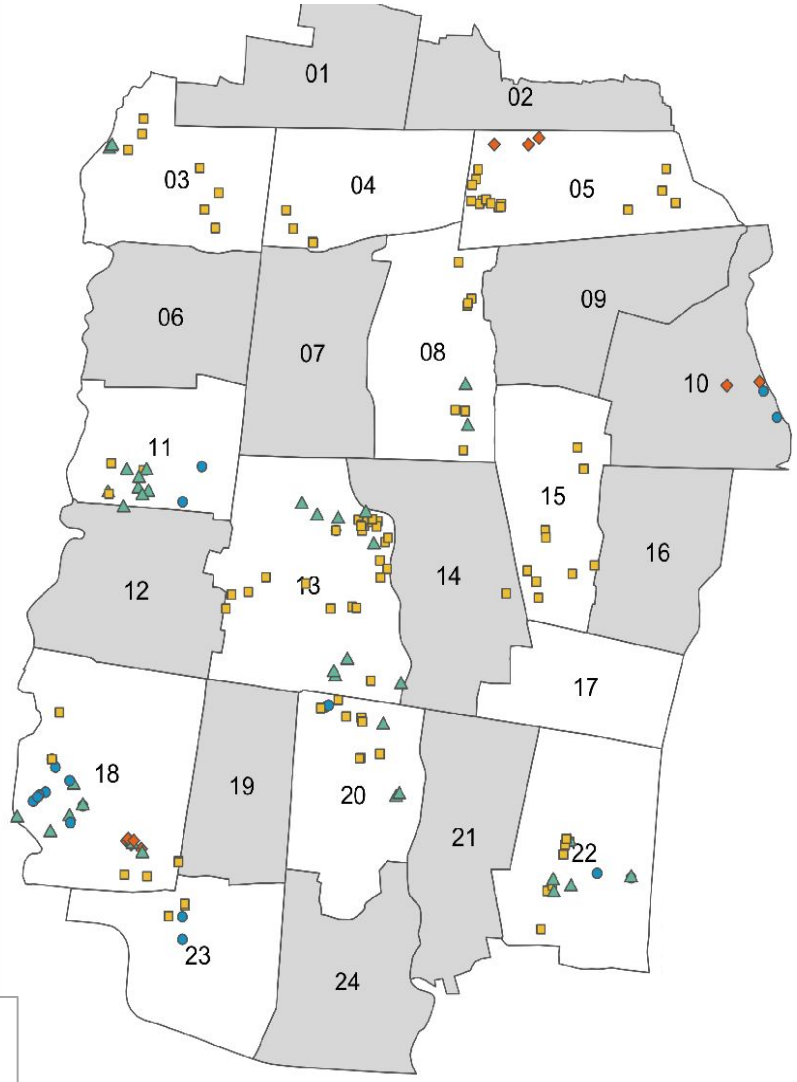


Atarini *et al.*, 2021

Au total, 385 cas de dengue ont été inclus (dont 328 sérotypés) 67 dans le groupe d'intervention ; 318 dans le groupe non traité

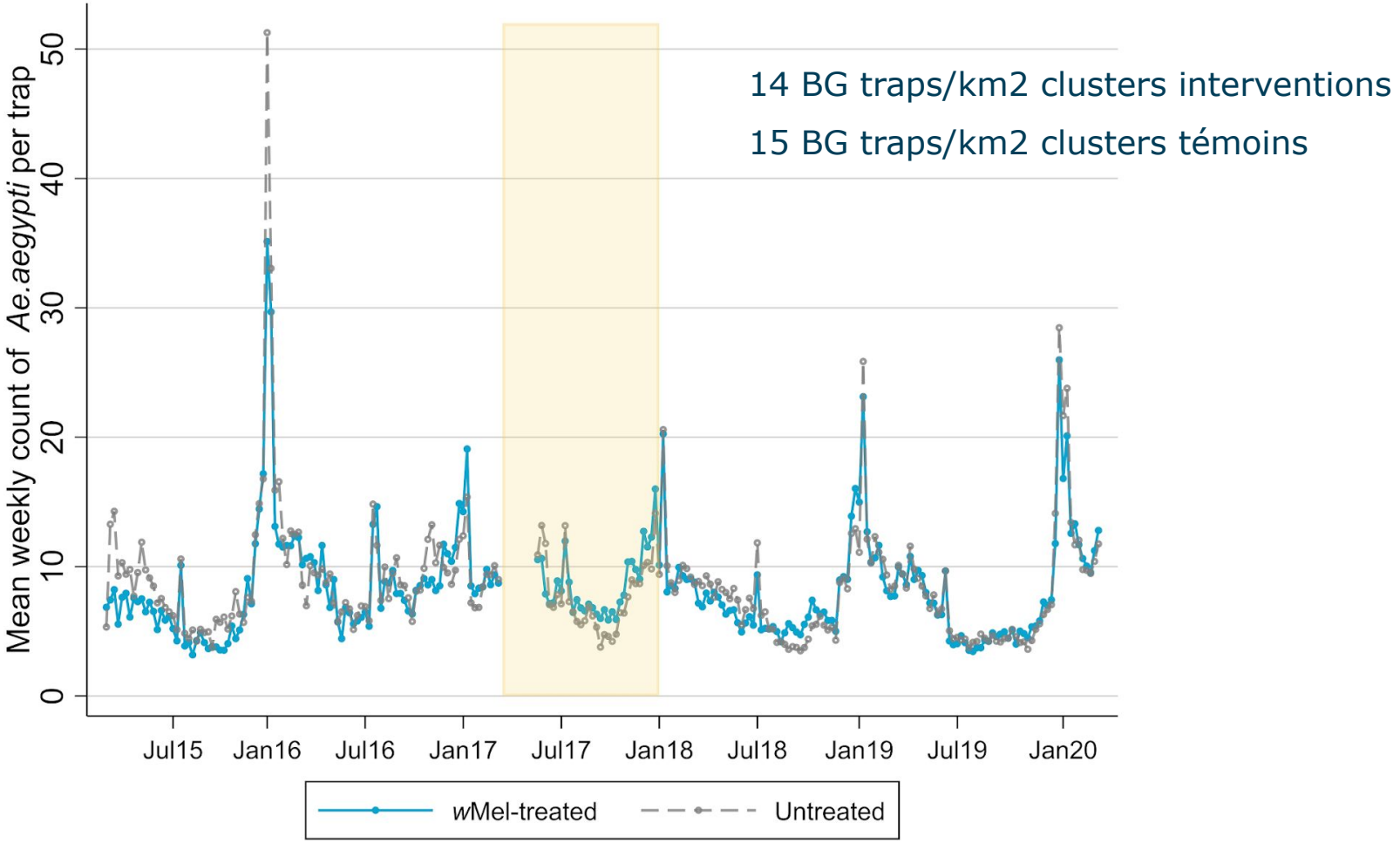
Wolbachia perturbe le regroupement spatio-temporel des cas de dengue





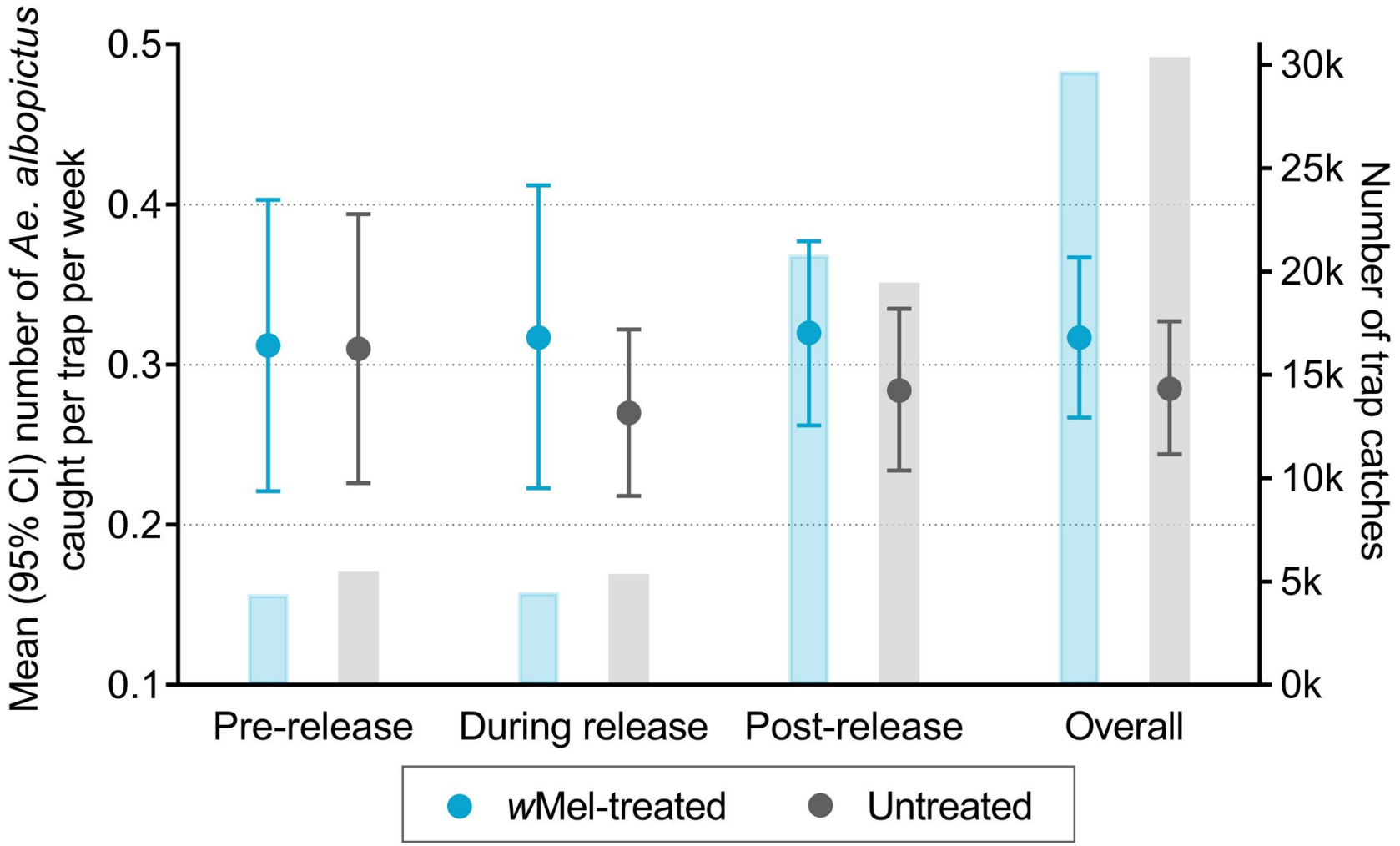
Sous-ensemble de 160 cas de dengue regroupés dans l'espace et le temps

Dufault *et al.*, 2022



L'introgression de *Wolbachia* n'a pas d'impact sur la prévalence d'*Aedes aegypti*

Tantowijoyo et al,. 2022

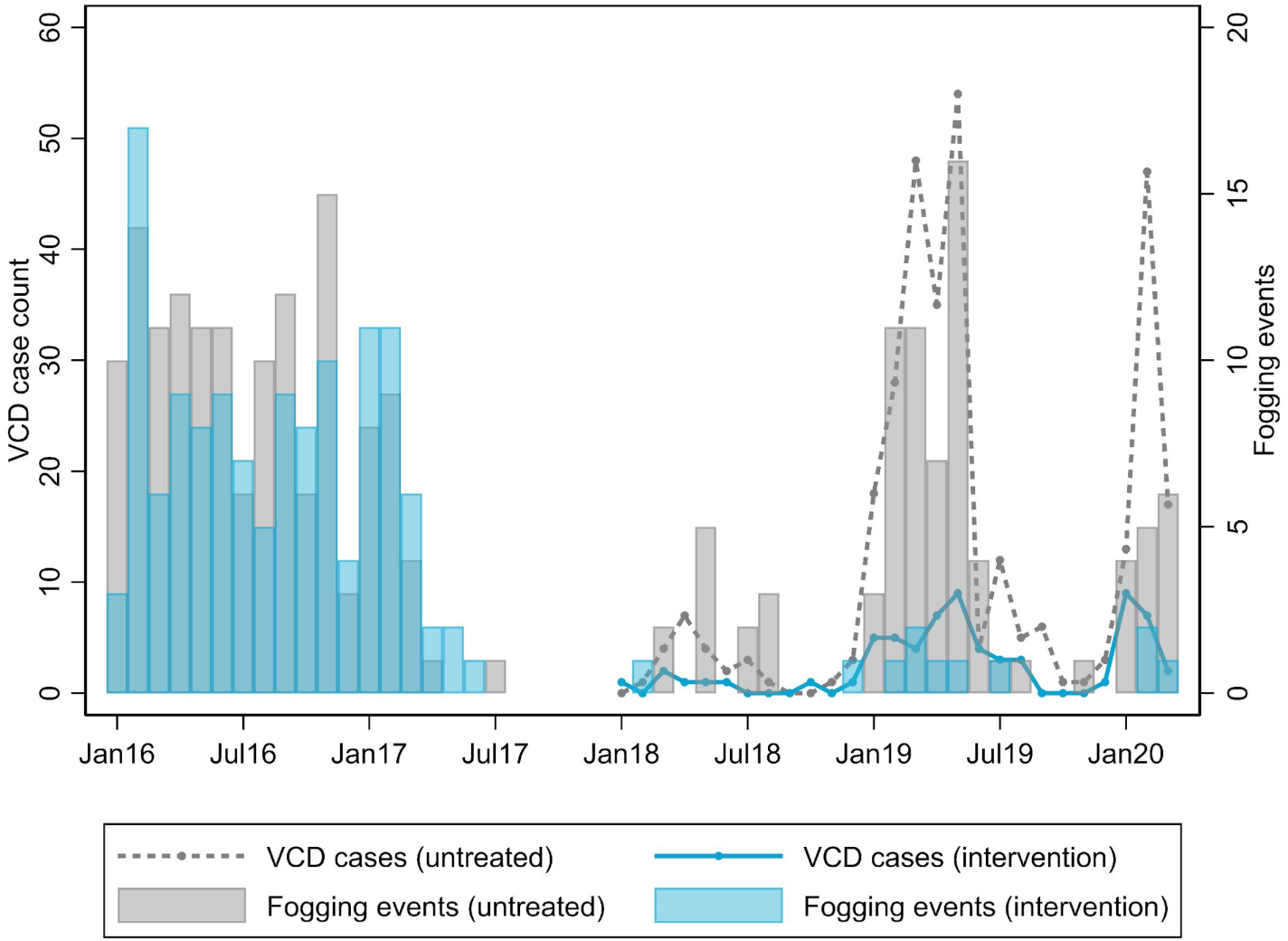


4 BG traps/km^2 clusters intervention ; 5 BG traps/km^2 clusters témoins avant l'introgression de *Wolbachia*

14 BG traps/km^2 clusters intervention ; 15 BG traps/km^2 clusters témoins pendant et après l'introgression de *Wolbachia*

L'introgression de *Wolbachia* n'a pas d'impact sur la prévalence d'*Aedes albopictus*

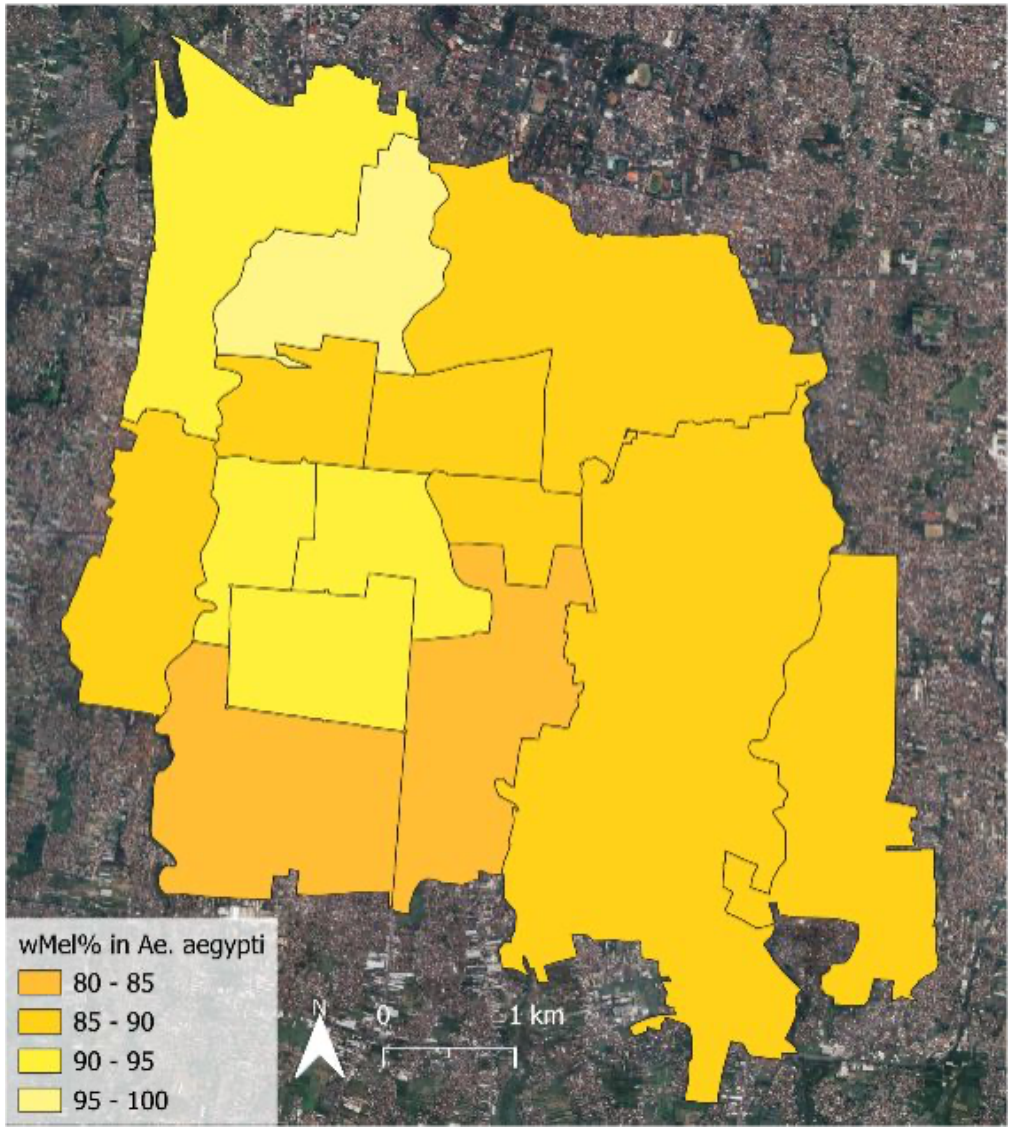
Tantowijoyo et al,. 2022



Cypermethrin in 2016-2018
Malathion in 2019-2020

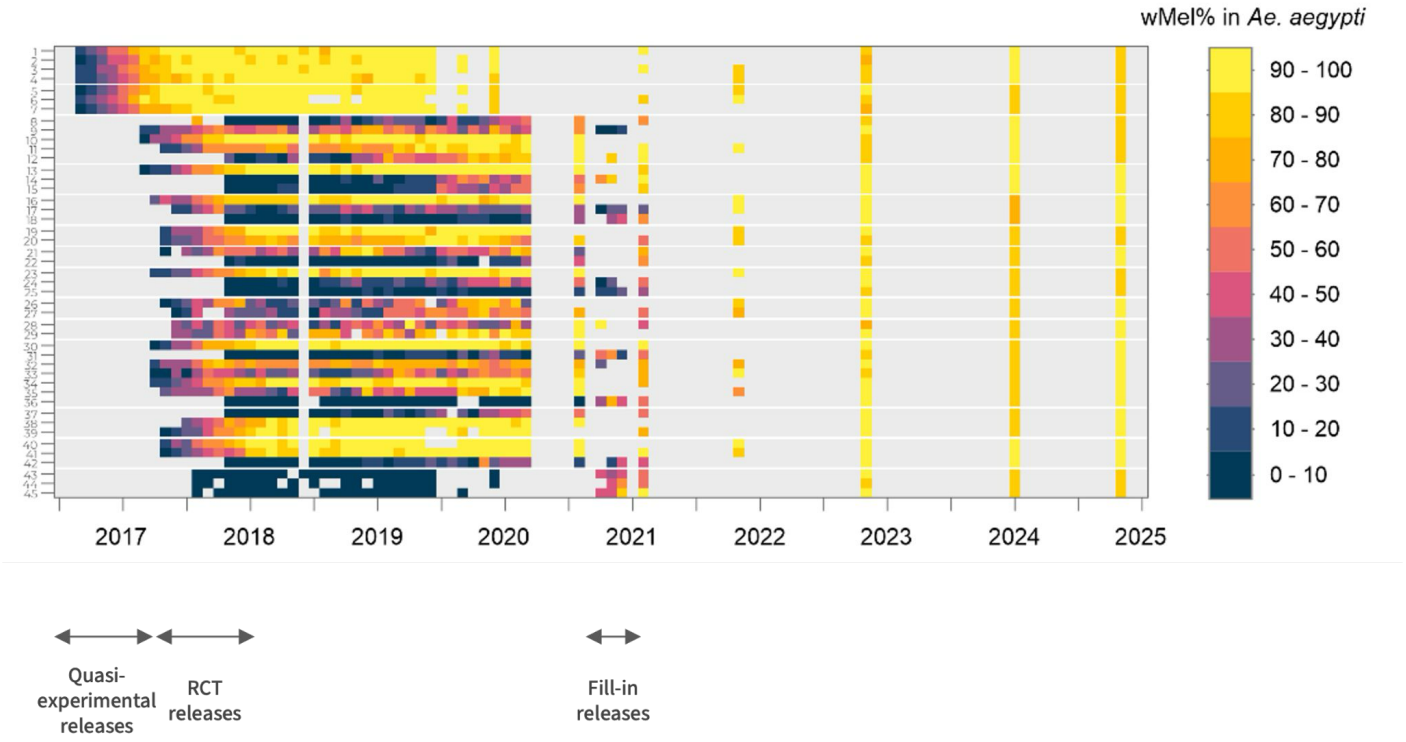
Diminution importante des épisodes de pulvérisation d'insecticides

Indriani et al,. 2023

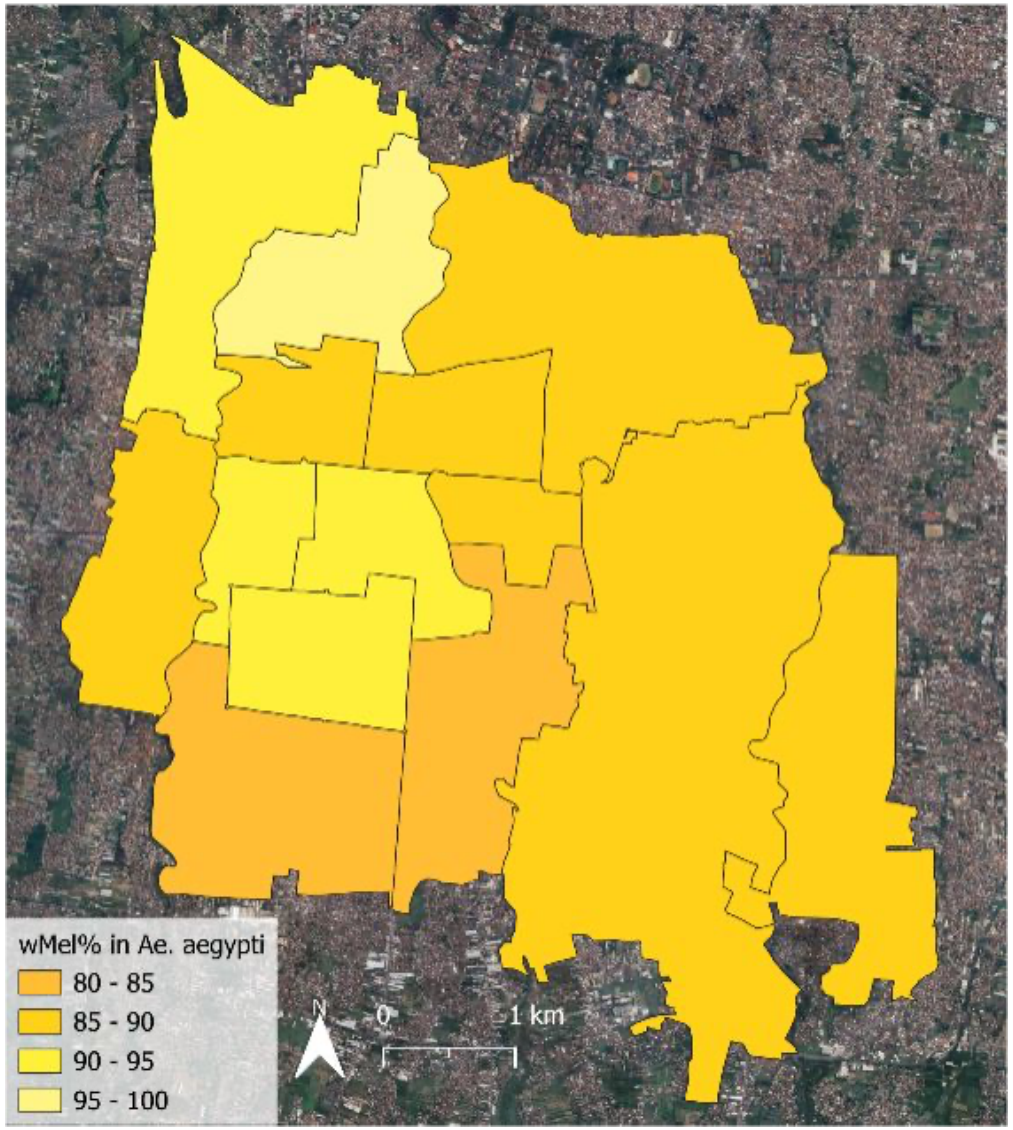


2023- 2025 Étude au long terme post-intervention sur Yogyakarta

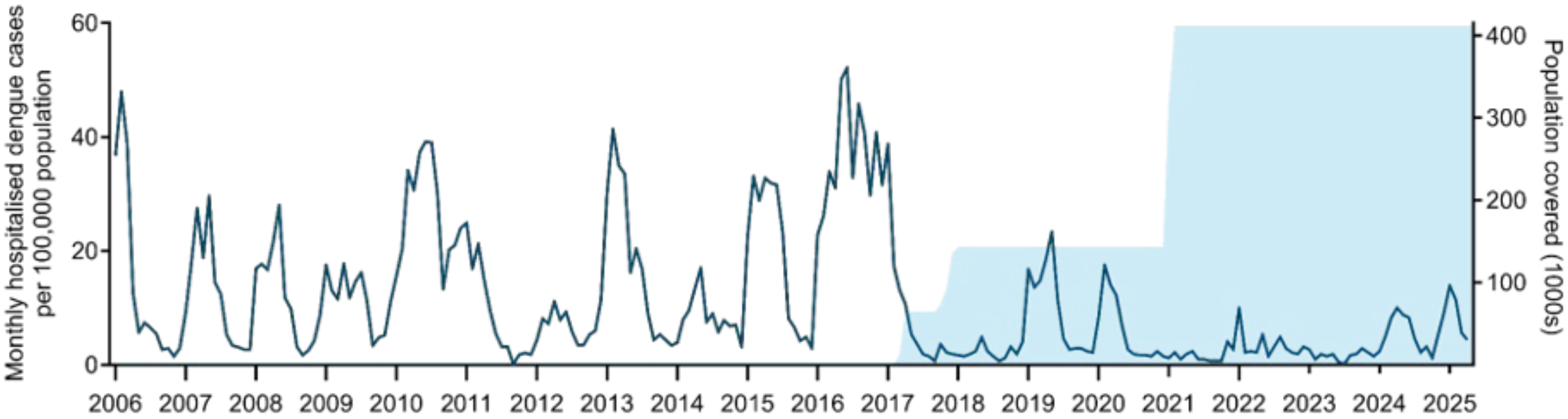
- Étude de séries chronologiques de cas de dengue sévère notifiés (2006-2025)
- *Objectif principal :* Évaluer l'impact du déploiement de *Wolbachia* sur le taux d'hospitalisation de cas de dengue.
- Zone intervention : 400 000 habitants ; 32 km^2



% d'*Aedes aegypti* positif pour *Wolbachia* sur une échelle de temps de 2017 à 2025 par village / sous-district



89% des *Aedes aegypti* collectés portent *Wolbachia* en 2024



Estimation d'une réduction de 78% de l'incidence de la dengue (cas hospitalisés)
Etude de séries chronologiques (2006-2025)

World Mosquito Program

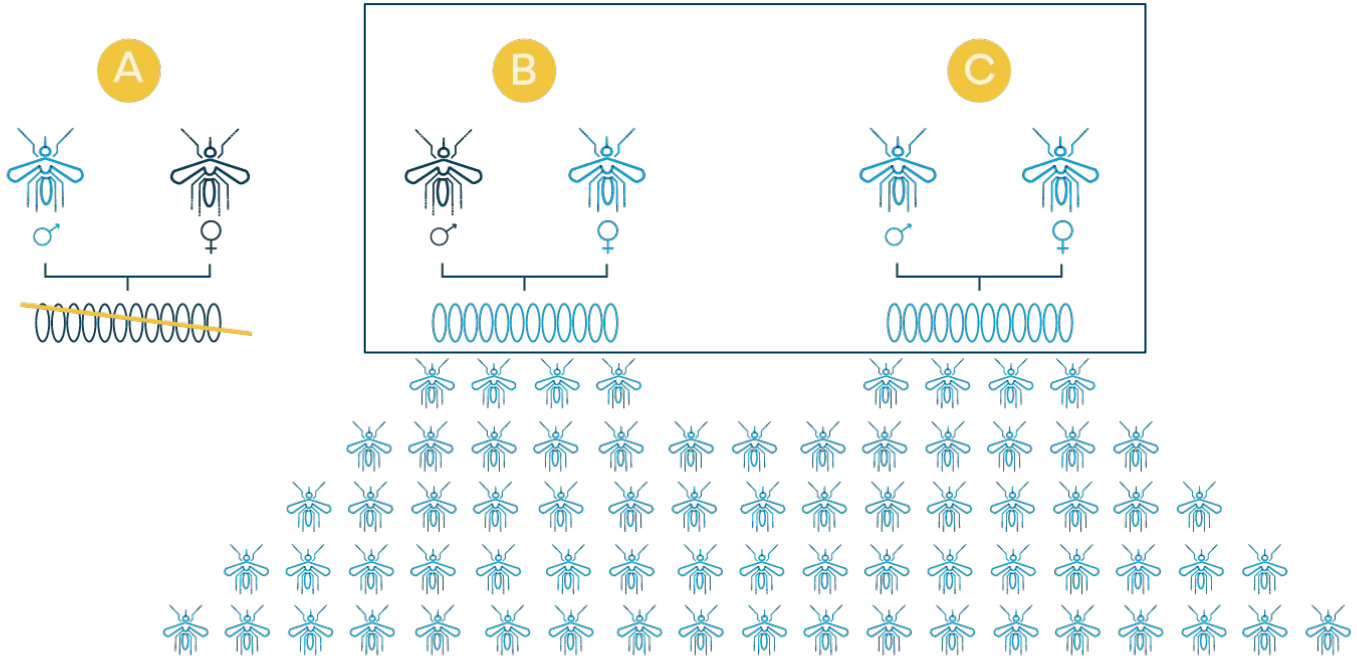
Yayasan TAHIJA

UNIVERSITAS GADJAH MADA

UC Berkeley

MONASH University

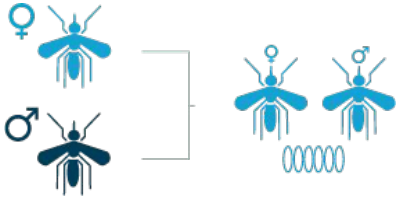
Extra slides



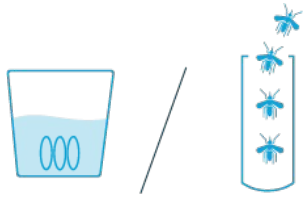
Wolbachia est transmise de façon **maternelle** et peut manipuler la reproduction de ses hôtes afin de favoriser son introgression dans les populations naïves (**incompatibilité cytoplasmique**).

Quelle est la méthode *Wolbachia* développée par WMP?

1 En laboratoire, introgression de *Wolbachia* dans une population autochtone d'*Aedes aegypti*, suivie d'une série de contrôles qualité (notamment l'interférence virale), avant de passer en production de masse et lâchers.

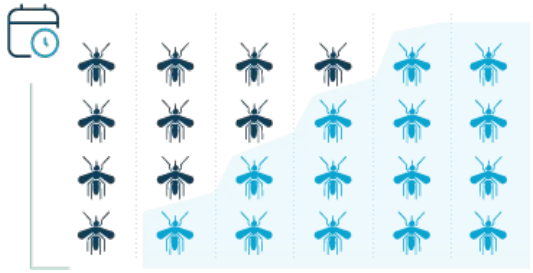


2 *Wolbachia-Aedes aegypti* sont lâchés durant 3 à 6 mois.



3 Les moustiques lâchés s'accouplent avec les populations sauvages d'*Aedes aegypti* et passent *Wolbachia*.

4 Lorsque les lâchers sont terminés, *Wolbachia* se répand dans la quasi-totalité des populations d'*Aedes aegypti* sauvages et se maintient.



5 Les communautés sont protégées par *Wolbachia* durablement et sans la nécessité de faire de nouveaux lâchers.

Moustiques avec *Wolbachia*

Moustiques sans *Wolbachia*

Essai randomisé

Yogyakarta divisée en 24 clusters ~1km^2

Randomisation

12 clusters experimentaux | **12 clusters témoins**

Patients avec de la fièvre (n= 53,924)

Eligibles et inscrits (n= 8,144)

- 1-4 jours de fièvre
- Agé de 3 – 45 ans
- Résidence dans la zone d'étude
- Aucun autre diagnostic
- Non inscrit durant les 4 semaines précédentes

6306 inclus dans l'analyse

Consentement

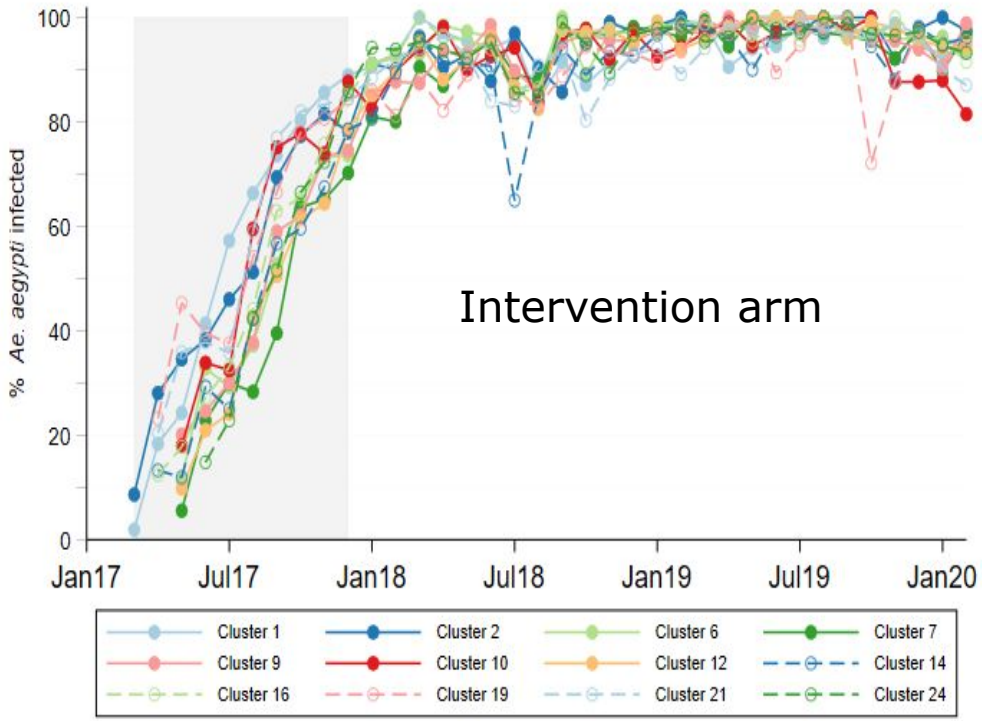
- Questionnaire d'inclusion complété (âge, sexe, adresse, historique déplacement 10 jours avant inclusion)
- Échantillion de sang

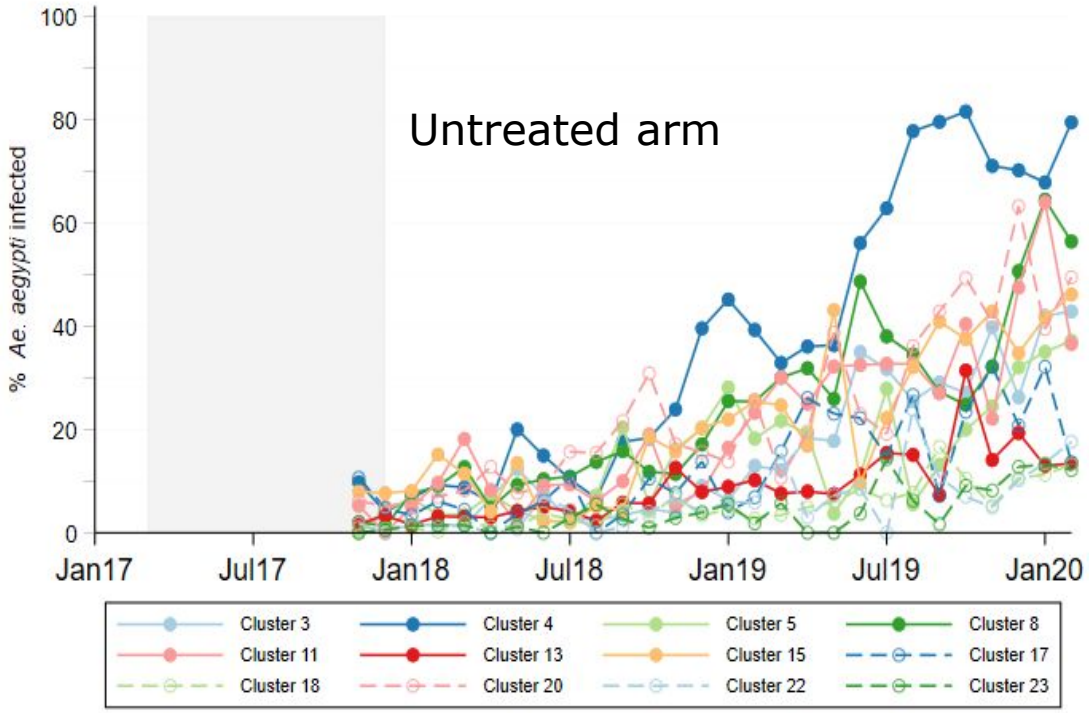
NS1 ELISA + DENV RT-PCR

NS1 et/ou RT-PCR positif → **Cas de dengue**

NS1 et RT-PCR négatif → Dengue IgM ELISA ; Chik and Zika RT-PCR

- IgM positif → **Exclus**
- Chik and Zika RT-PCR positif → **Cas de Chik ou Zika**
- Tests négatifs → **Contrôle**





- High and stable *Wolbachia* frequencies (average 93%) in intervention clusters throughout trial
- Some ‘contamination’ of untreated clusters after 1 year into clinical enrolment

Nouvelles méthodes de LAV : techniques en phase terrain

Wolbachia : stratégies de remplacement et de suppression

par Nicolas Pocquet

Wolbachia :
Stratégies de remplacement et de suppression

Nicolas POCQUET (PhD, HDR)

Responsable de l'unité d'entomologie médicale
Institut Pasteur de Nouvelle-Calédonie
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Journées scientifiques Arbo-France – Paris, France – 23 & 24 juin 2025

Contexte général

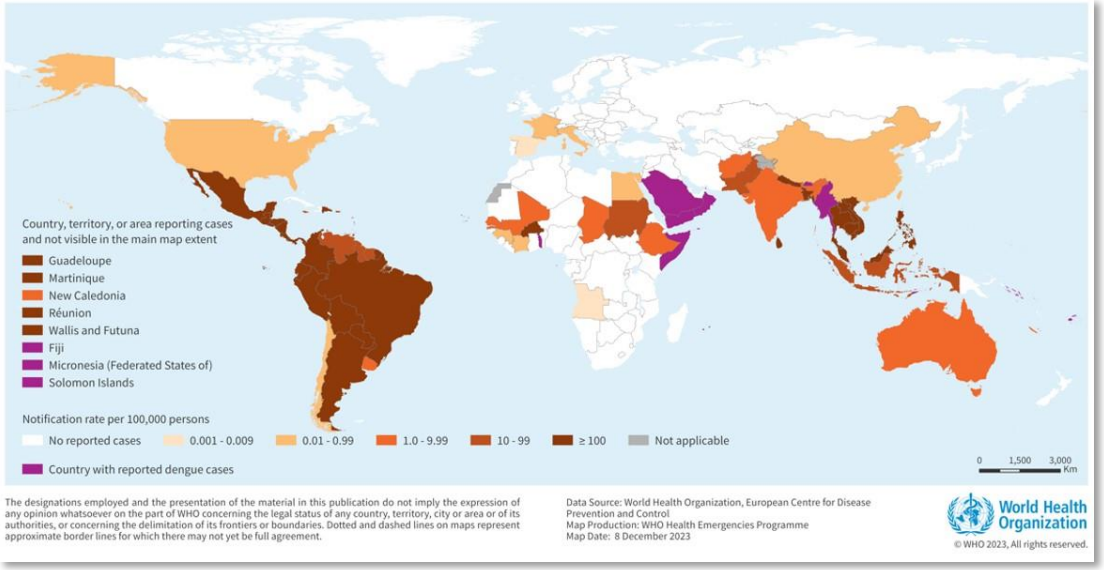
INSTITUT PASTEUR de Nouvelle-Calédonie

La dengue

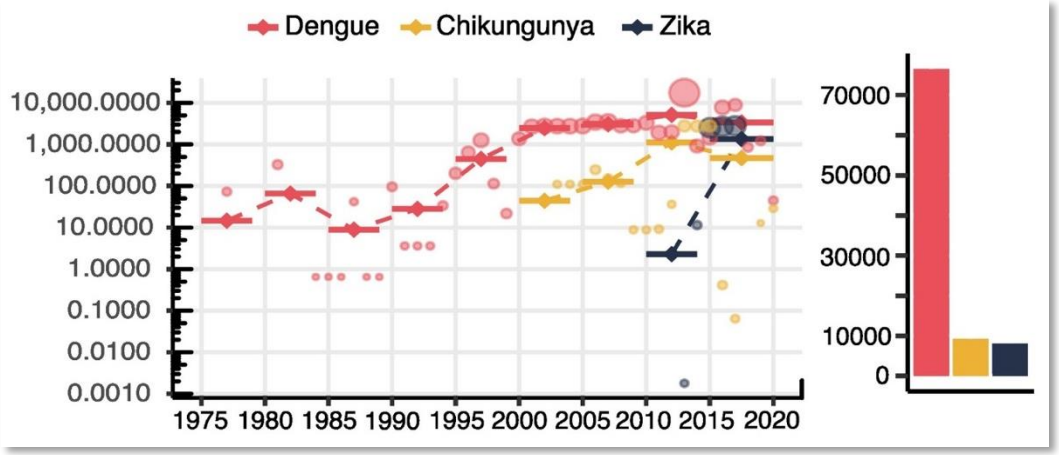
- Dans le monde
  - Nombre de cas multiplié par 10 en 20 ans (2000 – 2019)
  - Répartition mondiale
  - **> 5 millions de cas en 2023 → 5000 décès**

- Dans les pays et territoires insulaires du Pacifique
  - 9 pays touchés en 2023 (n = 21)
  - **> 13 000 cas en 2023** (28 % d'augmentation *vs* 2022)

- Au delà de l'impact humain…
  - Impact économique
    - Mondial 1975 – 2022 → **76,5 milliards US$**
      (Roiz et al., 2024)
    - Epidémie Nouvelle-Calédonie 2013 → **13 millions €**
      (estimation DASS-NC)



Carte des pays ayant signalé des cas de dengue autochtones, nov. 2022 à nov. 2023 (www.who.int ; WHO 2023)



Evolution et coût annuel (en millions US$) de la dengue, du chikungunya et du Zika (Roiz et al., 2024)

Limites de la LAV : l'exemple de la Nouvelle-Calédonie

INSTITUT PASTEUR de Nouvelle-Calédonie

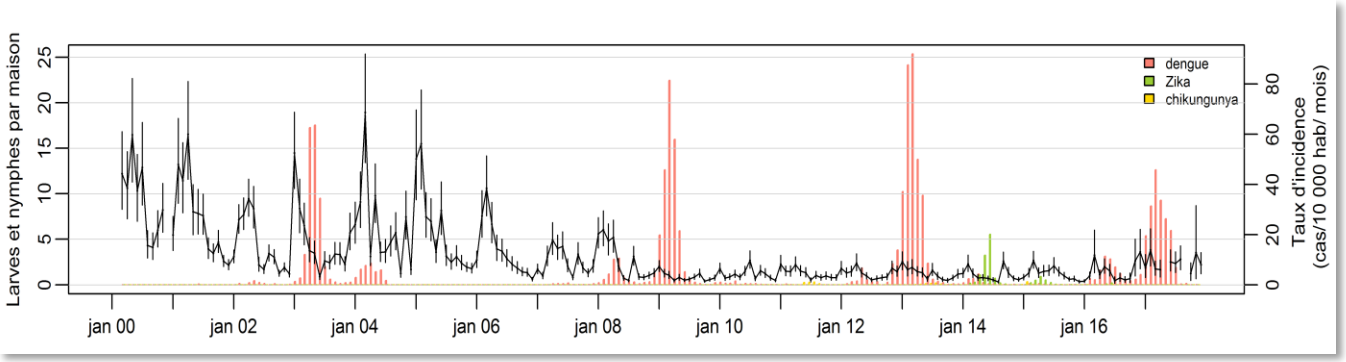
La Dengue en NC

- Un seul vecteur de DENV : *Aedes aegypti*

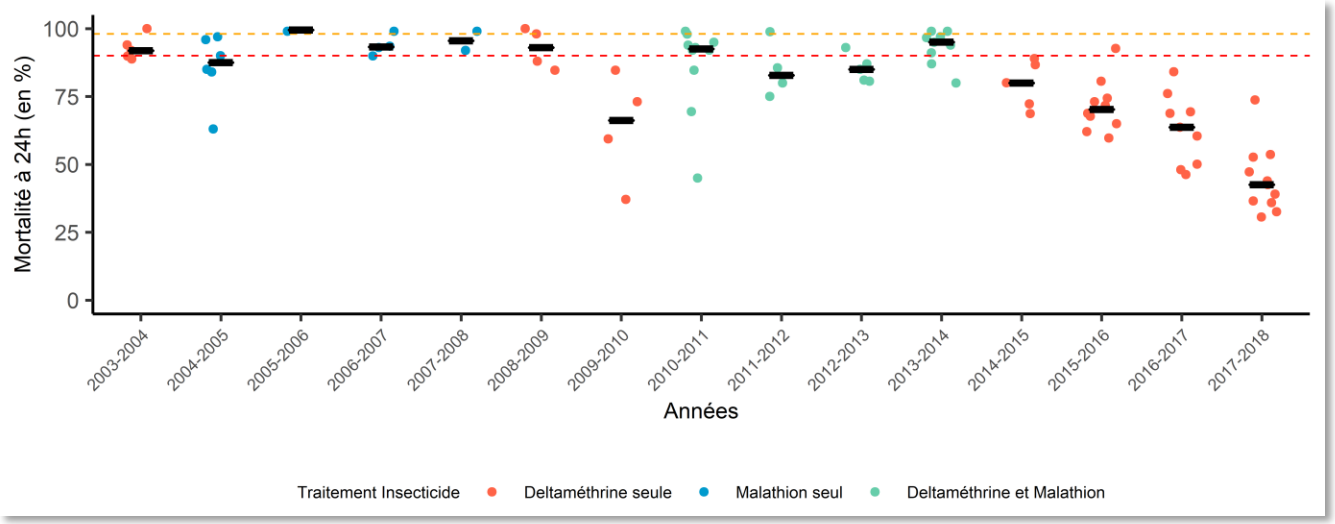
Efficacité limitée de la LAV conventionnelle

- **Communication / mobilisation sociale :**
  - Efficace sur les indices entomologiques
  - Pas d'impact visible sur les épidémies

- **Insecticides :**
  - Traitements adulticides peu efficaces (*e.g.*, ULV)
  - Augmentation de la **résistance à la deltaméthrine**
  - Pas d'insecticide alternatif
  - Réticence de la population



Moyennes du nombre de larves et nymphes retrouvées par maison à Nouméa entre 2000 et 2017



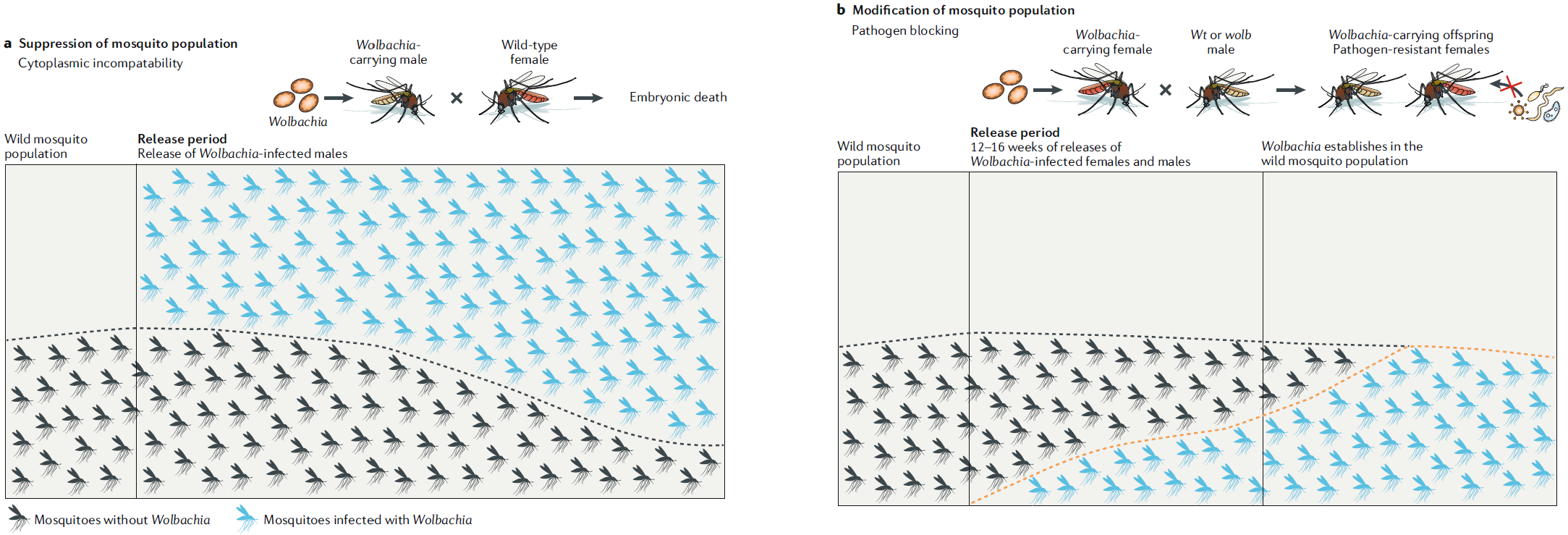
Evolution de la résistance à la deltaméthrine à Nouméa entre 2003 et 2018 (IPNC, données non publiées)

Nouvelles techniques de lutte basées sur *Wolbachia*

INSTITUT PASTEUR de Nouvelle-Calédonie

Technique de l'Insecte Incompatible vs Remplacement

- Propriétés de *Wolbachia*
  - Incompatibilité Cytoplasmique (IC)
  - Blocage de la réplication virale (DENV, ZIKV, CHIKV, YFV)



Comparaison des techniques basées sur l'utilisation de Wolbachia – (a) Technique de l'Insecte Incompatible ou TII, (b) Remplacement ou modification de la population (Flores & O'Neill, 2018)

Nouvelles techniques de lutte basées sur *Wolbachia*

INSTITUT PASTEUR de Nouvelle-Calédonie

Technique de l'Insecte Incompatible (TII)

Avantages

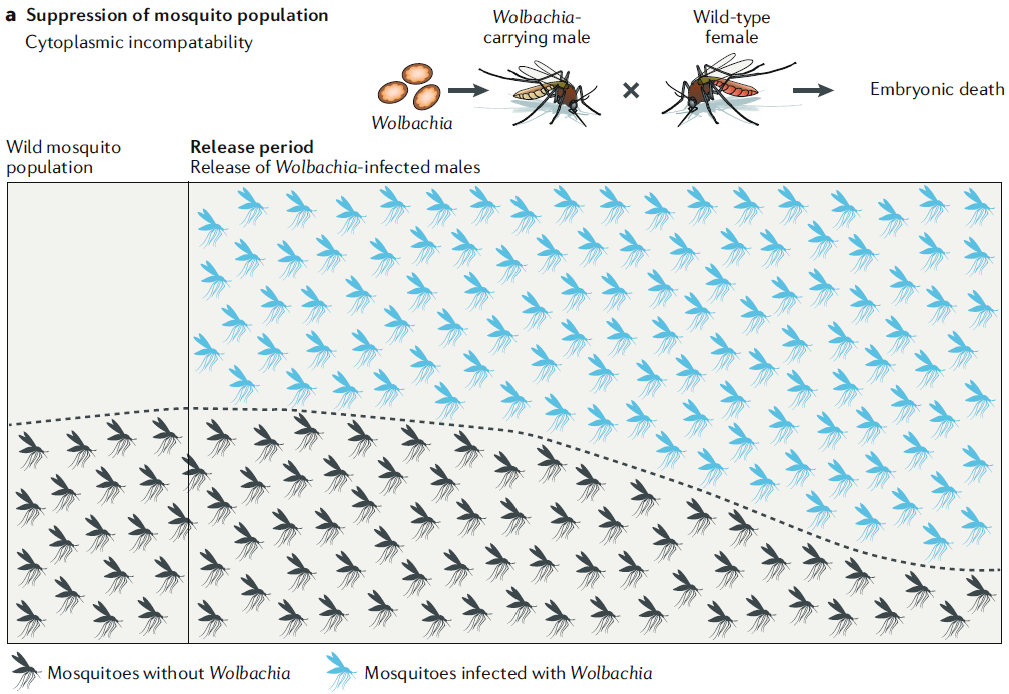
- Utilisable sur plusieurs vecteurs de DENV :
  - *Ae. aegypti*
  - Espèces du groupe Scutellaris (*e.g.*, *Ae. albopictus*)
  - Autres vecteurs d'arbovirus (*e.g.*, *Culex spp.*)
- Réduction de la nuisance
- Réduction de la transmission (*e.g.*, Singapour)

Inconvénients

- Production de masse et lâchers conséquents (comparable TIS)
- Importance du sexage pour éviter l'installation de *Wolbachia* :
  - TII + irradiation légère (stérilisation des femelles)
  - TII + nouvelles techniques de tris des nymphes
- Non durable en milieu ouvert (*i.e.*, Singapour)

Dans les territoires ultra-marins

- Expérimentation de terrain depuis 2015 sur *Ae. polynesiensis* en **Polynésie Française**
- Très bons résultats sur un atoll de PF, en association à des traitements larvicides (www.ilm.pf, 2025)



Technique de l'Insecte Incompatible ou TII (Flores & O'Neill, 2018)

Nouvelles techniques de lutte basées sur *Wolbachia*

INSTITUT PASTEUR de Nouvelle-Calédonie

Remplacement de population

Avantages

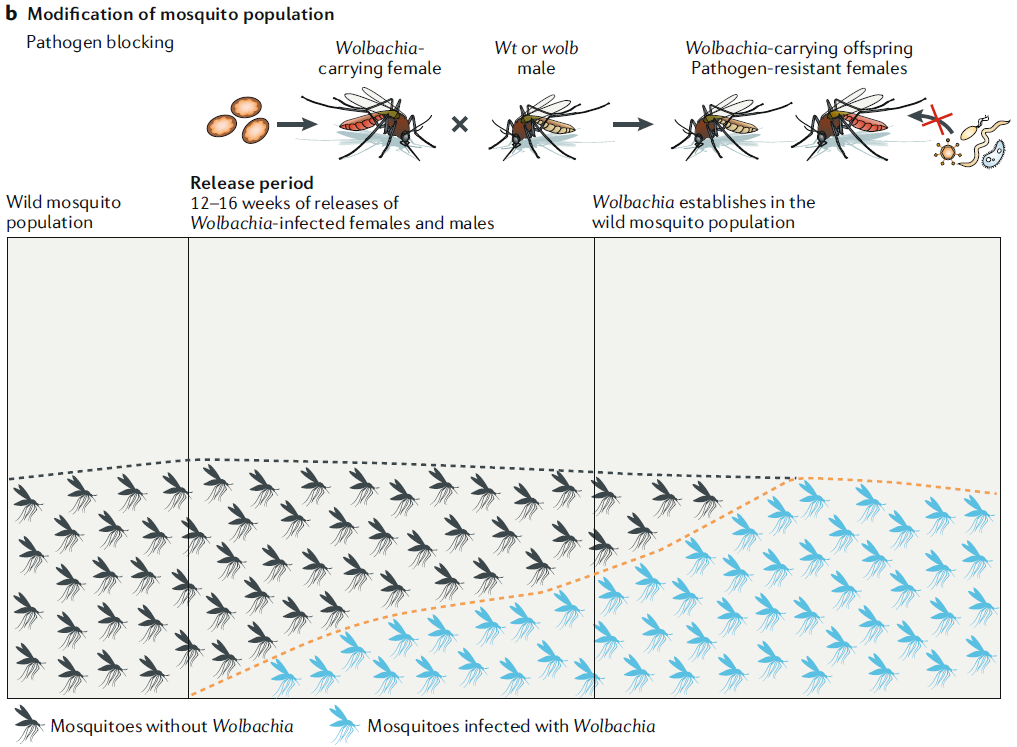
- Production de masse et lâchers réduits
- Pas de sexage nécessaire
- Durable une fois *Wolbachia* établie
- Réduction importante de la transmission (*i.e.*, Indonésie : OR = 0,23)

Inconvénients

- Uniquement utilisable sur *Ae. aegypti*
- Pas de réduction de la nuisance

Dans les territoires ultra-marins

- Implémentée depuis 2018 en **Nouvelle-Calédonie**



Remplacement ou modification de la population (Flores & O'Neill, 2018)

WMP-NC : World Mosquito Program Nouvelle-Calédonie

Le World Mosquito Program

- Technique de remplacement basée sur *Wolbachia*
- Programme à but non lucratif
- Porté par la Monash University
- Implémenté dans 14 pays (depuis 2011 en Australie)

Cadre du projet en NC

- **Financeurs** : Gouv NC, Université de Monash (WMP), IPNC, Villes de Nouméa, Mont-Dore, Dumbéa, Païta, Fonds Pacifique, Province Sud
- **Collaborateurs** : WMP, IPNC, DASS-NC, Mairies de Nouméa, Mont-Dore, Dumbéa et Païta
- **PI :** Nadège ROSSI
- **Budget global** : 6,7 M€ (subvention : 3,5 M€)
- **Période** : 2018 – 2024

WMP-NC :
Souche NC-*w*Mel

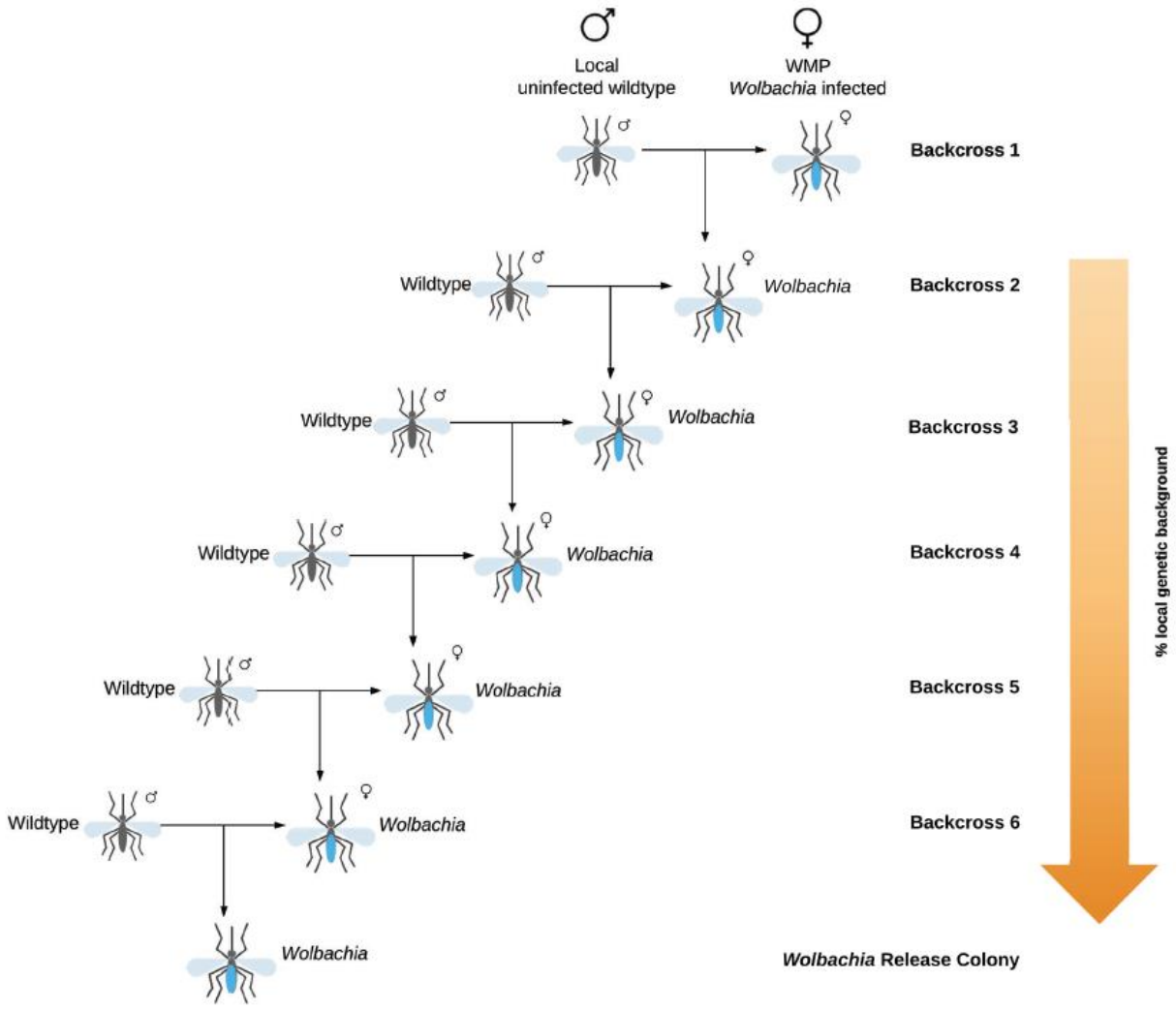
INSTITUT PASTEUR de Nouvelle-Calédonie

Création de la souche

- Souche **NC-*w*Mel** générée à partir de la souche *w*Mel australienne
  - 6 étapes de Backcross
  - Mâles **WT** x Femelles *w*Mel

  → Obtenir une souche génétiquement proche des moustiques **WT** (98,5 %)

- Maintien de la souche **NC-*w*Mel**
- Contrôle de la fréquence de *Wolbachia* à chaque génération



Etapes de rétrocroisements (WMP)

WMP-NC :
Fitness de la souche

INSTITUT PASTEUR de Nouvelle-Calédonie

Tests de Fitness

- **Transmission maternelle**
  - Croisements ♂ **WT** x ♀ **NC-*w*Mel**
  - 96 % de transmission de *Wolbachia* à la descendance

- **Incompatibilité Cytoplasmique**
  - Croisements ♂ **NC-*w*Mel** x ♀ **WT**
  - 0 % d'éclosion des œufs : IC complète

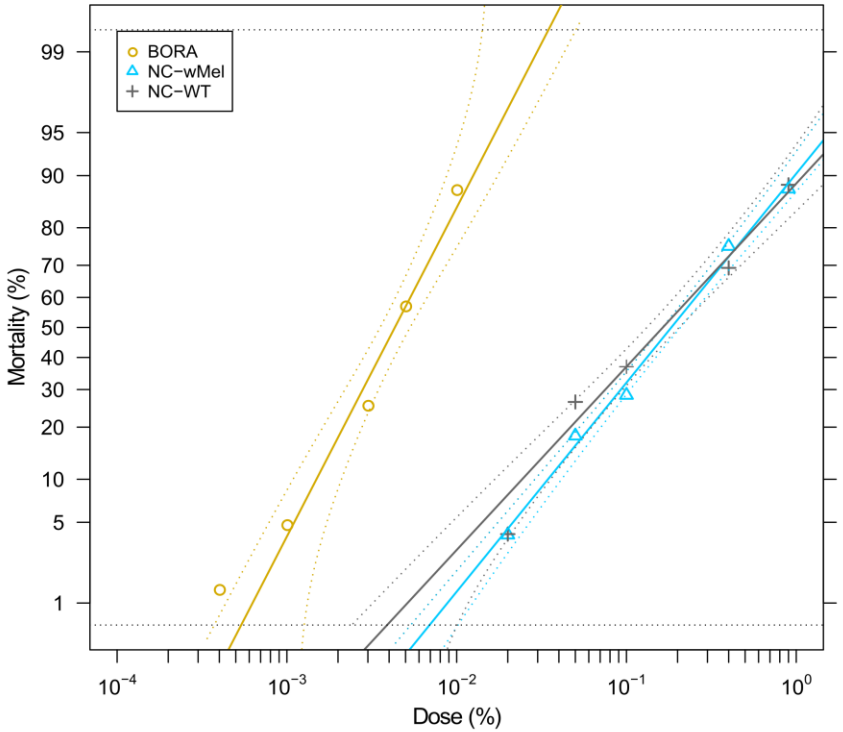
- **Fécondité et Fertilité**
  - Croisements ♂ **NC-*w*Mel** x ♀ **NC-*w*Mel**
  - 22 œufs par femelle (43 pour la souche **WT**)
  - 53 % d'éclosion des œufs (77 % pour la souche **WT**)

- **Résistance aux insecticides**
  - Paramètre important pour les lâchers
  - Forte résistance de la souche **NC-*w*Mel** (RR_{50} = 42)
  - Niveau de résistance équivalent aux **WT**


PLOS NEGLECTED TROPICAL DISEASES

RESEARCH ARTICLE

Assessment of fitness and vector competence of a New Caledonia *w*Mel *Aedes aegypti* strain before field-release



Tests doses réponses à la deltaméthrine sur les souches bora (sensible) WT et NC-wMel (résistantes) (Pocquet et al., 2021)

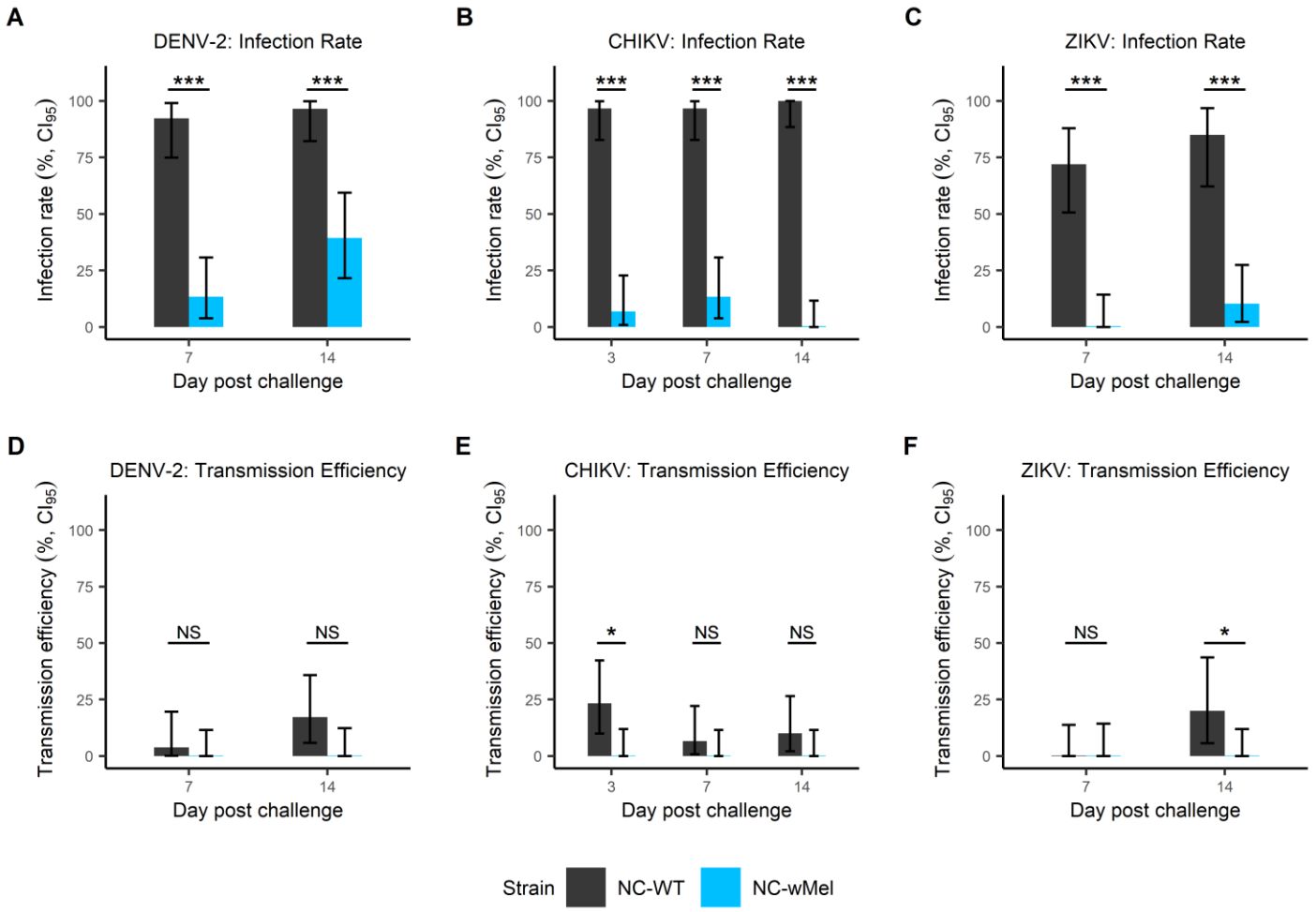
WMP-NC :
Blocage de l'infection

INSTITUT PASTEUR de Nouvelle-Calédonie

Repas infectieux

- Virus ayant circulés en NC
  - DENV-2
  - CHIKV
  - ZIKV

→ Réduction significative du taux d'infection pour la souche **NC-*w*Mel**
→ Pas de virus détecté dans la salive



Taux d'infection et efficacités de transmission pour les souches d'Ae. aegypti NC-WT et NC-wMel exposées à des repas de sang infectés par du DENV-2, du CHIKV ou du ZIKV.
(Pocquet et al., 2021)

WMP-NC :
Blocage de la réplication virale

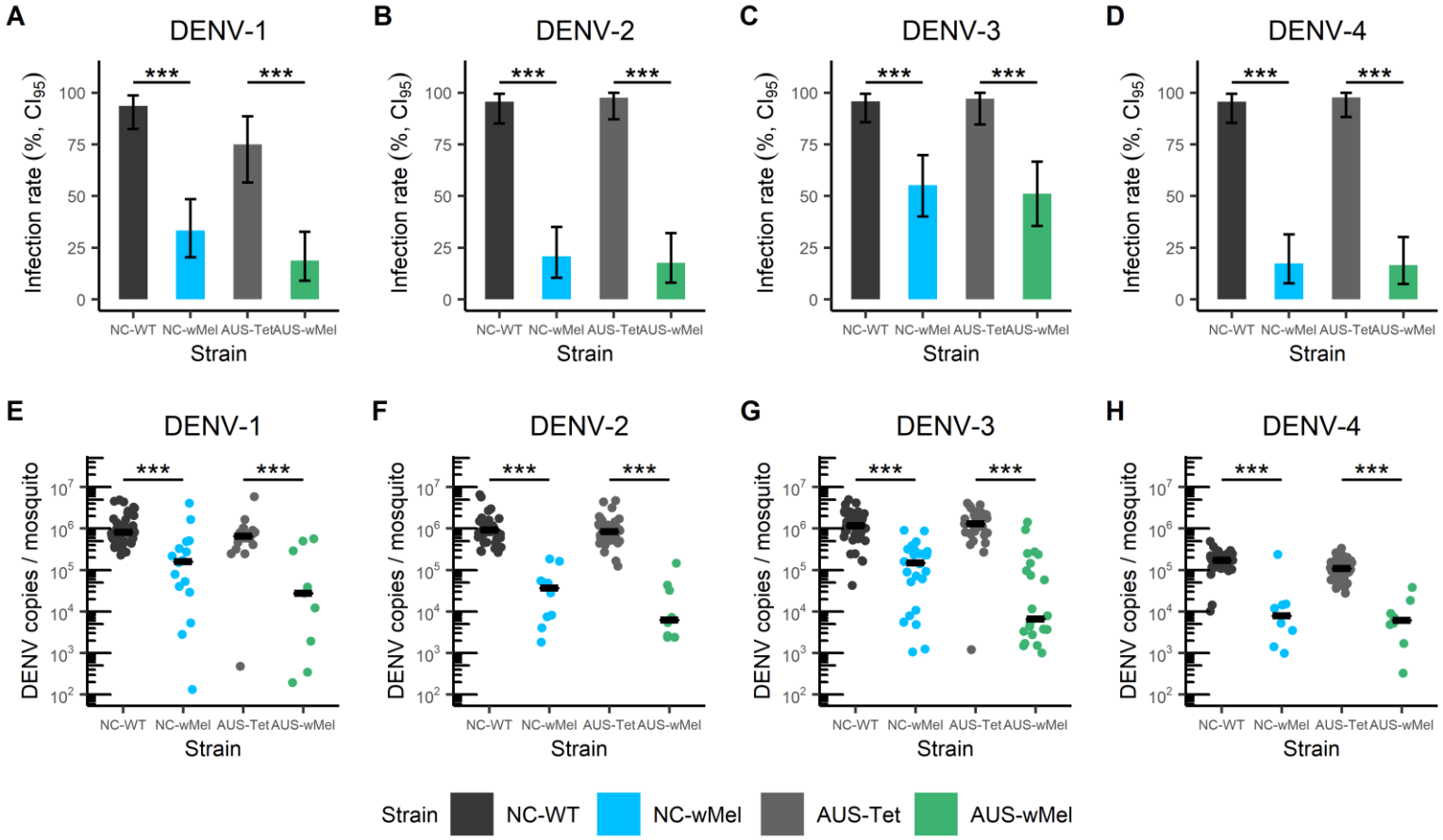
INSTITUT PASTEUR de Nouvelle-Calédonie

Injections intrathoraciques

- Virus de référence
- DENV-1 à 4

→ Réduction significative du taux d'infection pour la souche **NC-*w*Mel**, comparable à la souche **AUS-*w*Mel**

→ Réduction significative du nombre de copies de DENV chez les moustiques **NC-*w*Mel** infectés vs **NC-WT** infectés



Taux d'infection et nombre de copie d'ARN viral pour les souches d'Ae. aegypti WT et wMel (NC et Australie) exposées à des micro-injections des 4 sérotypes de DENV.
(Pocquet et al., 2021)

WMP-NC :
Autorisation et acceptation de la population

INSTITUT PASTEUR de Nouvelle-Calédonie

Autorisation de lâchers

- NC : autonome sur les questions d'environnement et de santé
- Comité d'éthique de Nouvelle-Calédonie
- Autorisation du gouvernement de la Nouvelle-Calédonie

Acceptation de la population

- Campagne de communication et engagement communautaire
- Evaluation de l'acceptation du projet par la population
- Constitution d'un groupe de référence communautaire
- Sondage de la population :
    - 94% de personnes favorables à Nouméa
    - 91% et 93% à Dumbéa et Mont Dore (2 phases)
    - 94% à Païta

Campagne de communication WMP-NC Nouméa (WMP-NC, 2018)

WMP-NC :
Déploiement

INSTITUT PASTEUR de Nouvelle-Calédonie

Phase I (Nouméa)

- Août 2019 – Juillet 2021
- 2800 points de lâchers / 230 BG
- 12 M de moustiques relâchés / 26 à 63 semaines de lâchers

Phase II (Dumbéa / Mt Dore)

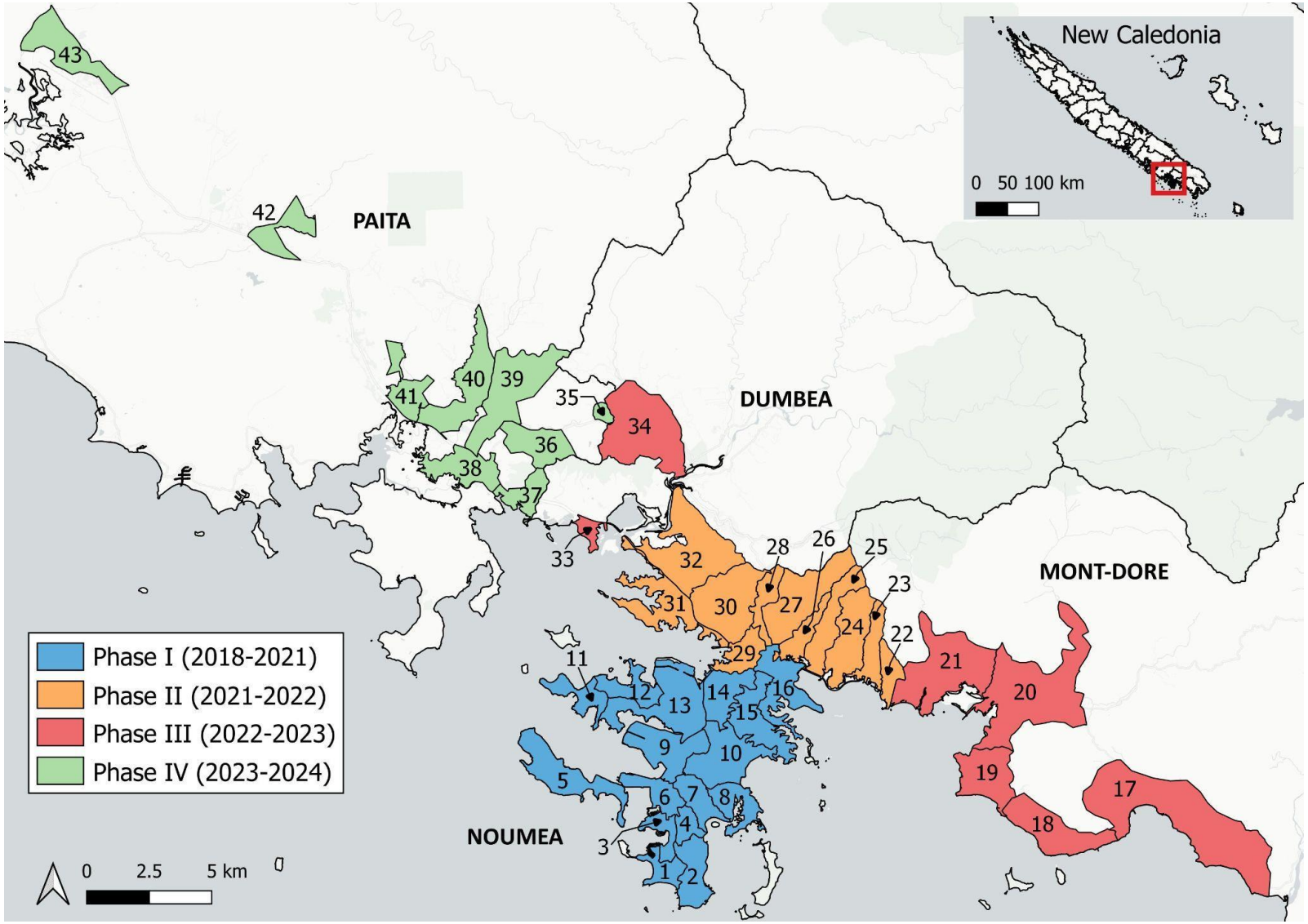
- Janvier 2021 – Juillet 2022
- 2000 points de lâchers / 120 BG
- 4 M de moustiques / 24 semaines

Phase III (Dumbéa / Mt Dore)

- Novembre 2022 – Juin 2023
- 1400 points de lâchers / 50 BG
- 4 M de moustiques / 22 semaines

Phase IV (Païta)

- Novembre 2023 – Mai 2024
- 1400 points de lâchers / 93 BG
- 4 M de moustiques / 24 semaines



Zones et phases de lâchers (Rossi et al., in prep.)

WMP-NC :
Résultats entomologiques

INSTITUT PASTEUR de Nouvelle-Calédonie

Phase I (Nouméa)

- **87 %** de moustiques porteurs de *Wolbachia* 33 mois post-lâchers

Phase II (Dumbéa / Mt Dore)

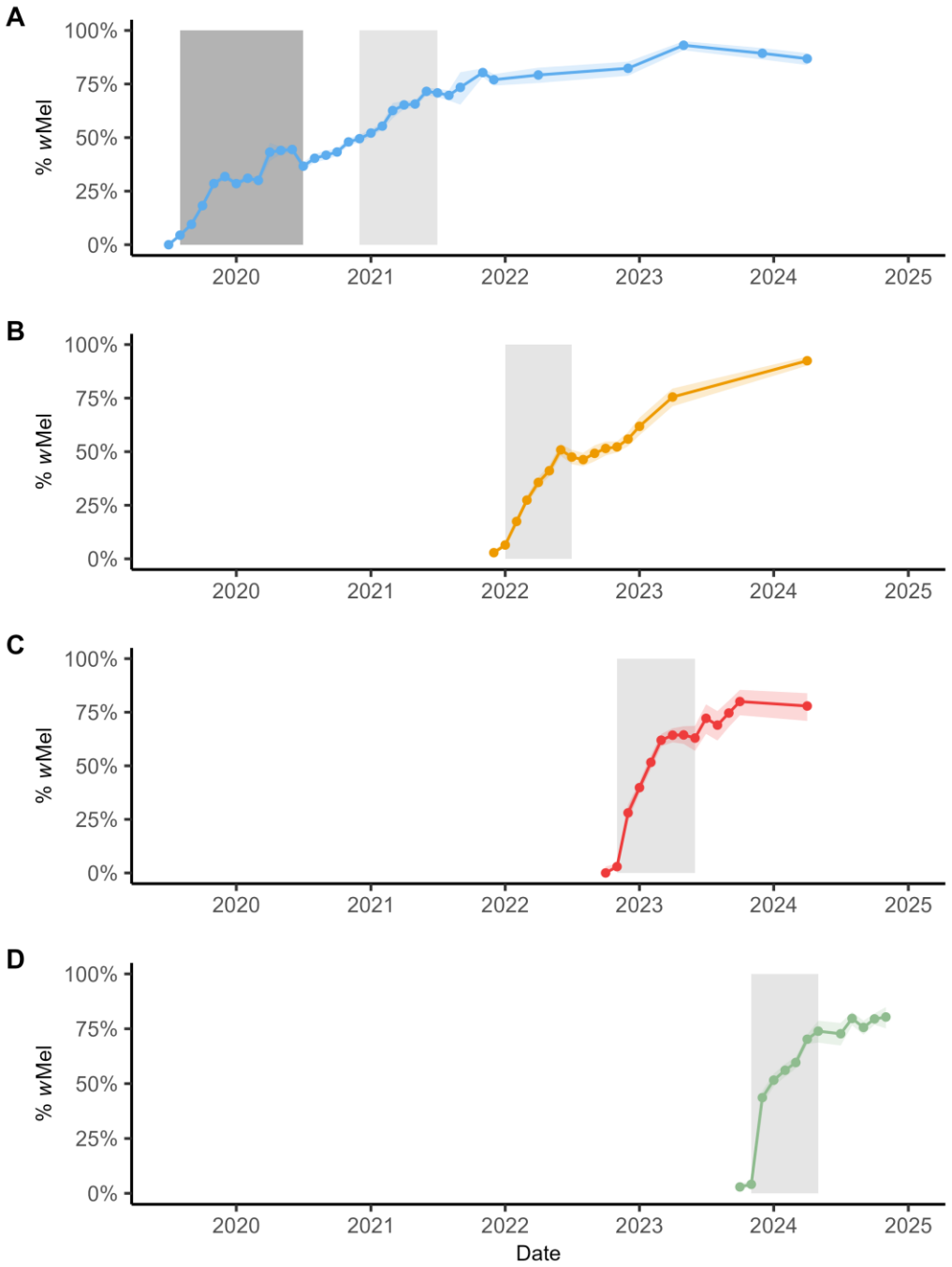
- **92 %** de moustiques porteurs de *Wolbachia* 21 mois post-lâchers

Phase III (Dumbéa / Mt Dore)

- **78 %** de moustiques porteurs de *Wolbachia* 10 mois post-lâchers

Phase IV (Païta)

- **80 %** de moustiques porteurs de *Wolbachia* 6 mois post-lâchers



Evolution de la fréquence des moustiques infectés par Wolbachia (±IC_{95}) sur les différentes zones de lâchers

(Rossi et al., in prep.)

WMP-NC :
Résultats épidémiologiques

INSTITUT PASTEUR de Nouvelle-Calédonie

Suivi épidémiologique

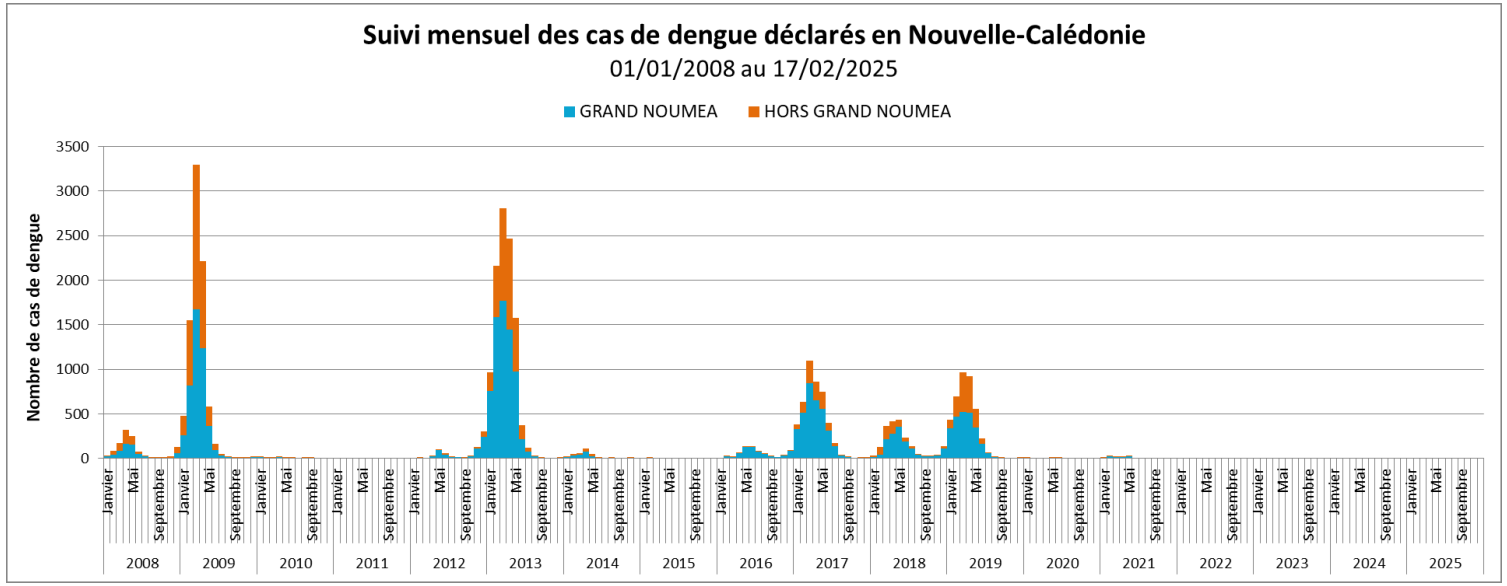
- Suivi des cas de dengue par les autorités de santé (**DASS-NC**)

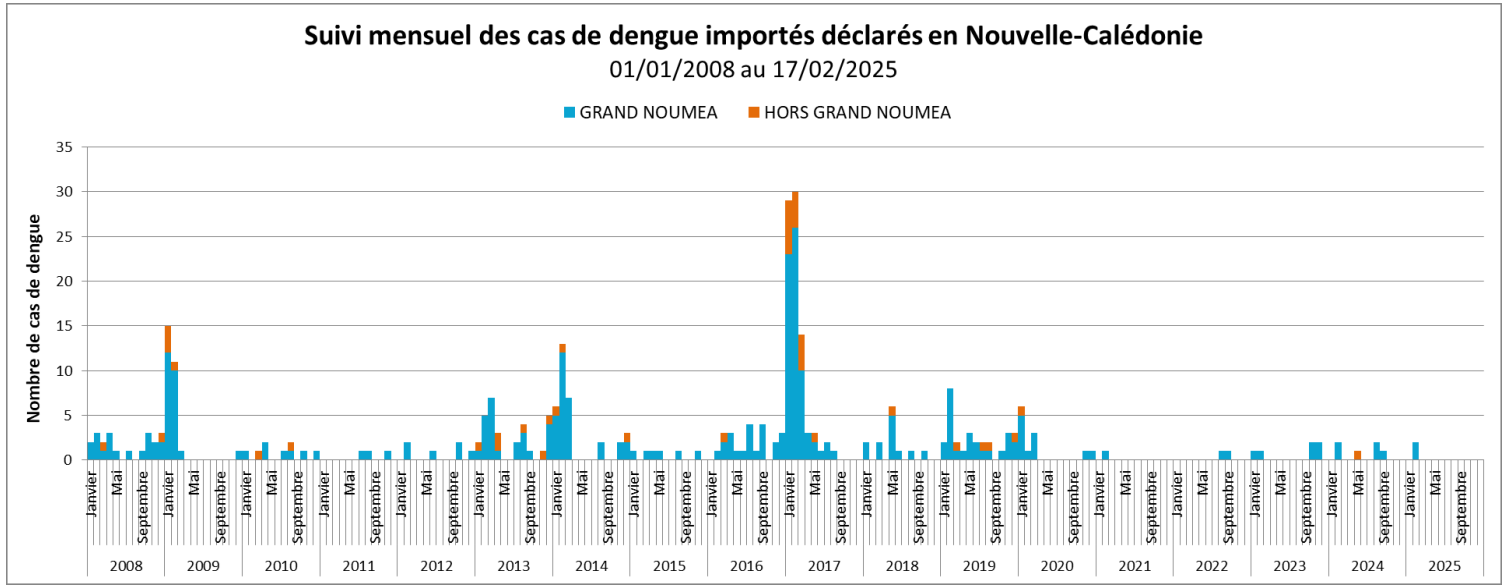
  → Pas d'épidémie depuis 2019

  → Faible transmission autour des cas importés

Suivi long terme en cours

- Suivi entomologique une fois par an
- Suivi épidémiologique en continu
- Projets de recherche en parallèle





Suivi mensuel des cas de dengue autochtones et importés en NC entre 2008 et 2025

(DASS-NC, données non publiées)

WMP-NC :

Maintien du blocage à 4 ans

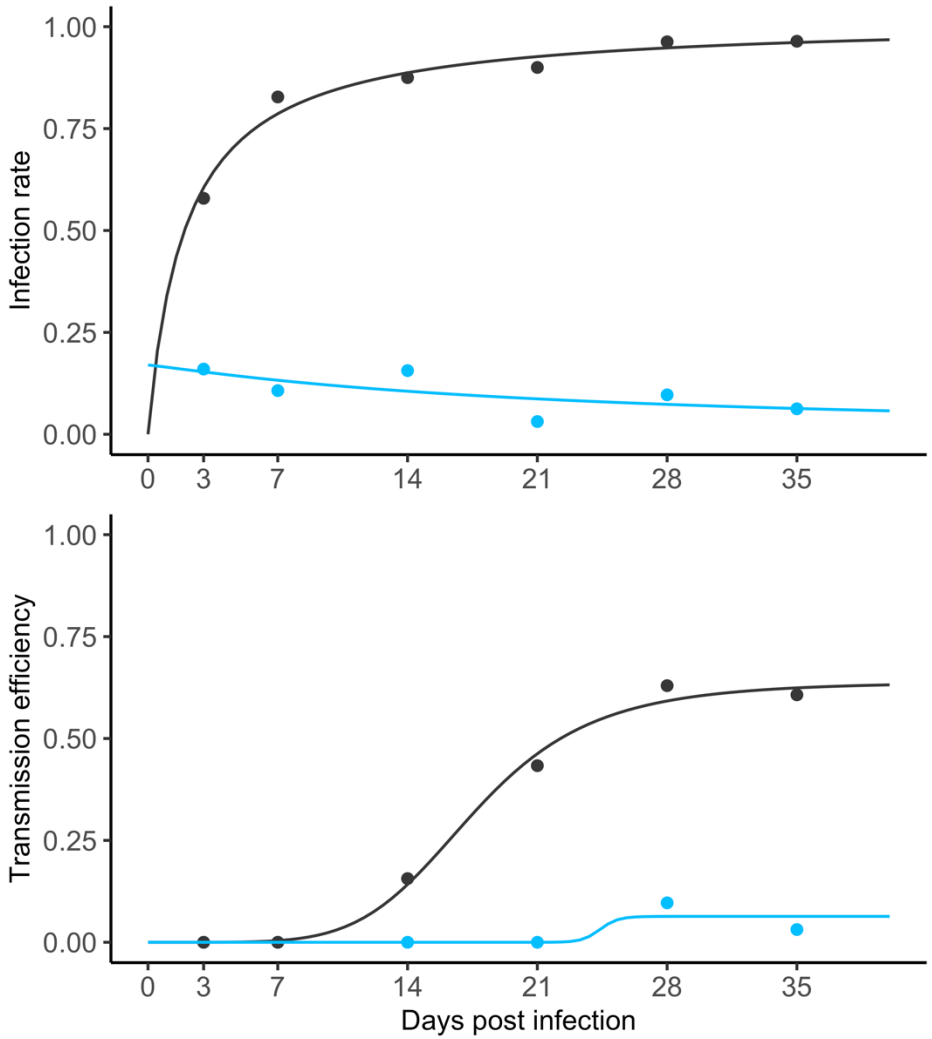
Projet PYRWOL (IPP / IPNC)

- Bourse de thèse ANRS-MIE / Arbo-France
- Populations de terrain échantillonnées en 2024 :
  - Nouméa : *Ae. aegypti* ***w*Mel**
  - Ouvéa : *Ae. aegypti* **WT**
- Infections expérimentales au DENV2

Dupuis B.

Résultats

- Infection
  - **WT** : 88 % à 14 dpi (maximum à 100 %)
  - ***w*Mel** : 16 % à 14 dpi (maximum à 17 %)
- Efficacité de transmission
  - **WT** :
    Premiers moustiques infectants à 14 dpi
    EIP_{50} = 18 jours (IC_{95} : 13 – 21)
    64 % de moustiques infectants au maximum
  - ***w*Mel** :
    Premiers moustiques infectants à 28 dpi
    EIP_{50} non calculable
    6 % de moustiques infectants au maximum



Taux d'infection et efficacités de transmission du DENV2 par des populations d'Ae. aegypti prélevées en NC en 2024 (Dupuis et al., données non publiées)

Conclusion

INSTITUT PASTEUR de Nouvelle-Calédonie

Contrôle des vecteurs et des arboviroses :

- Traitements conventionnels (ULV et thermo-nébulisation) encore très présents
- Efficacité entomologique faible, voir inexistante sur populations résistantes
- Efficacité épidémiologique peu évaluée

***Wolbachia* : outil d'intérêt en LAV**

- Recherches ET application de la recherche en cours :
  - **TII** :
    - 8 essais de terrain de TII ou TII + TIS publiés (7 entre 2019 et 2024)
    - *Ae. albopictus* (2) et *Ae. aegypti* (6)

      (Revue dans Rahul *et al.*, 2024)
  - **Remplacement** :
    - Implémenté dans 14 pays sur *Ae. aegypti* (WMP)
    - Technique d'intérêt pour la Guyane, la Guadeloupe et la Martinique (*i.e.*, *Ae. aegypti* seul vecteur de DENV)

Merci pour votre attention

Nouvelles méthodes de LAV : techniques en phase terrain

TIS classique et TIS boostée

par Jéremy Bouyer

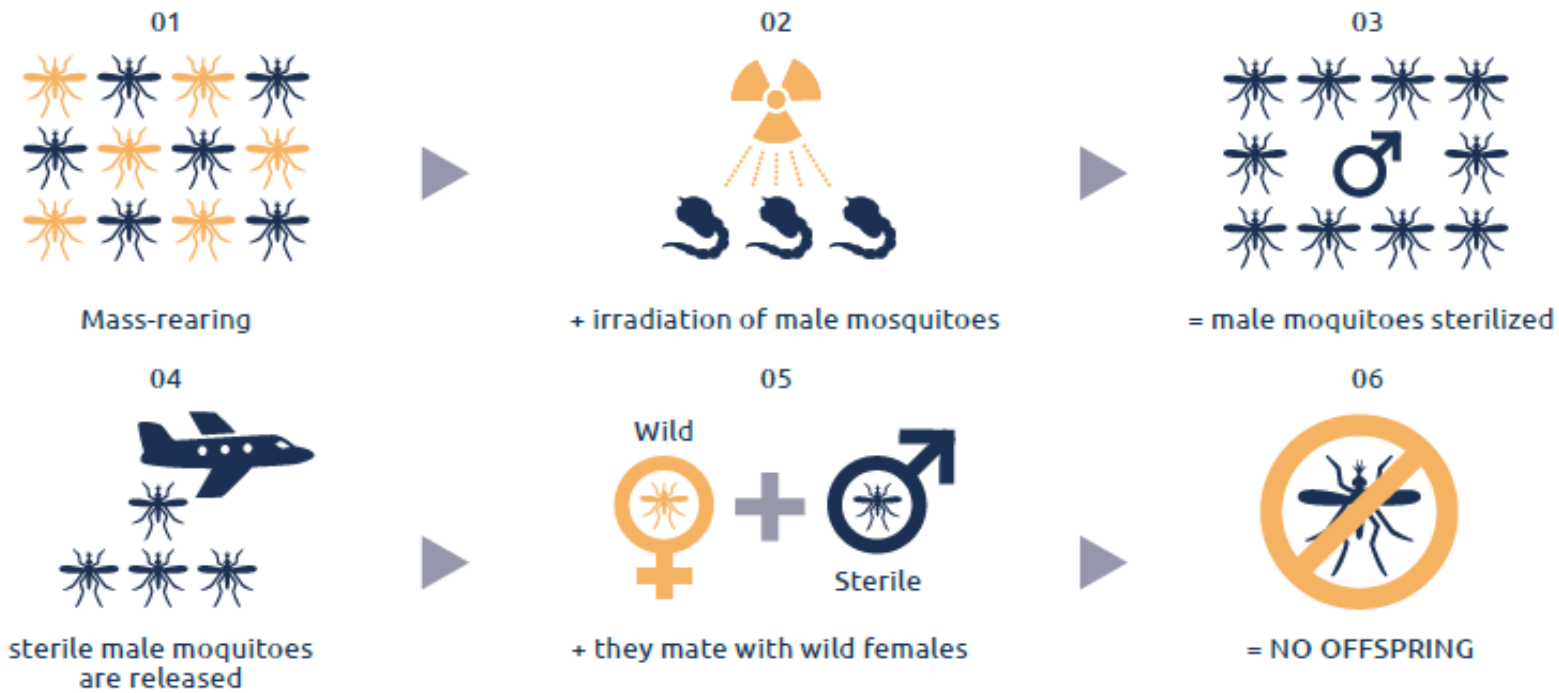
Journées scientiques :
Moyens innovants de lutte contre les vecteurs d'arbovirus.
Institut Pasteur, Paris

TIS classique et TIS boostée

Jérémy Bouyer

23 Juin 2025

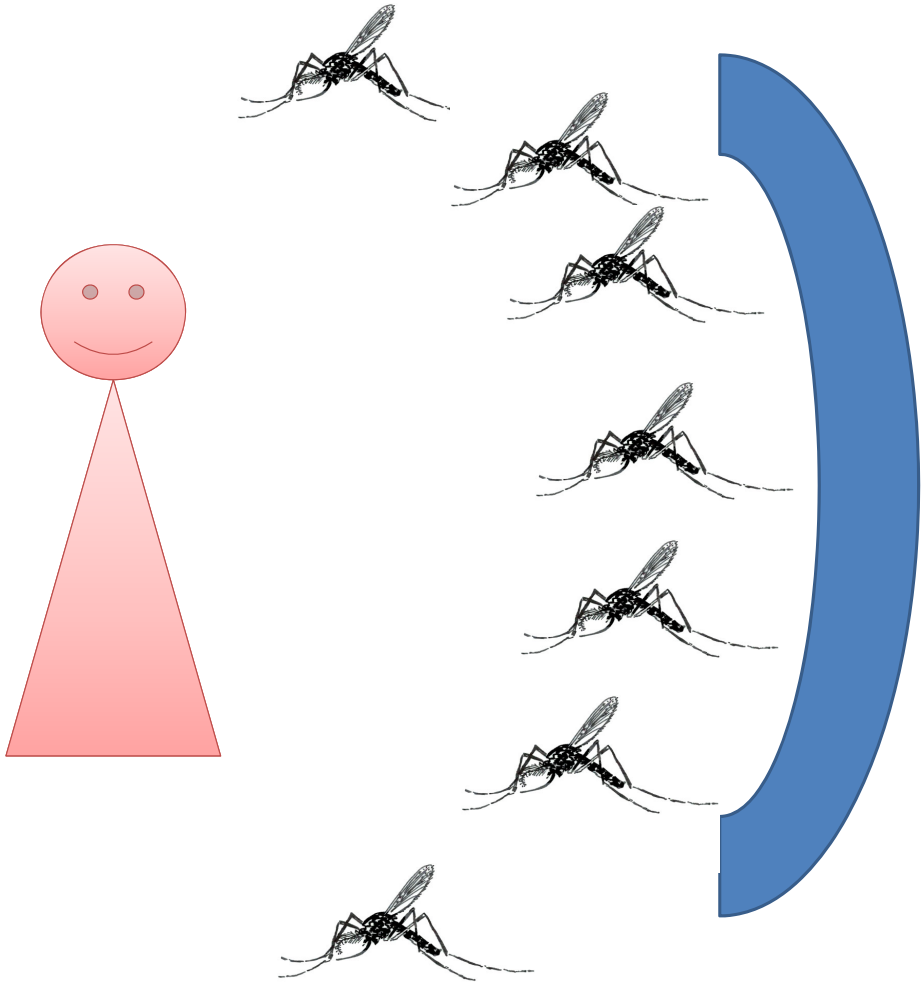
Sterile Insect Technique (SIT)



http://www-naweb.iaea.org/nafa/resources-nafa/SIT-Mosquitoes-LR.mp4

Joint FAO/IAEA Centre
Nuclear Techniques in Food and Agriculture

Sterile Insect Technique (SIT): impact of mating harassment…



nature communications

Article

https://doi.org/10.1038/s41467-024-46268-x

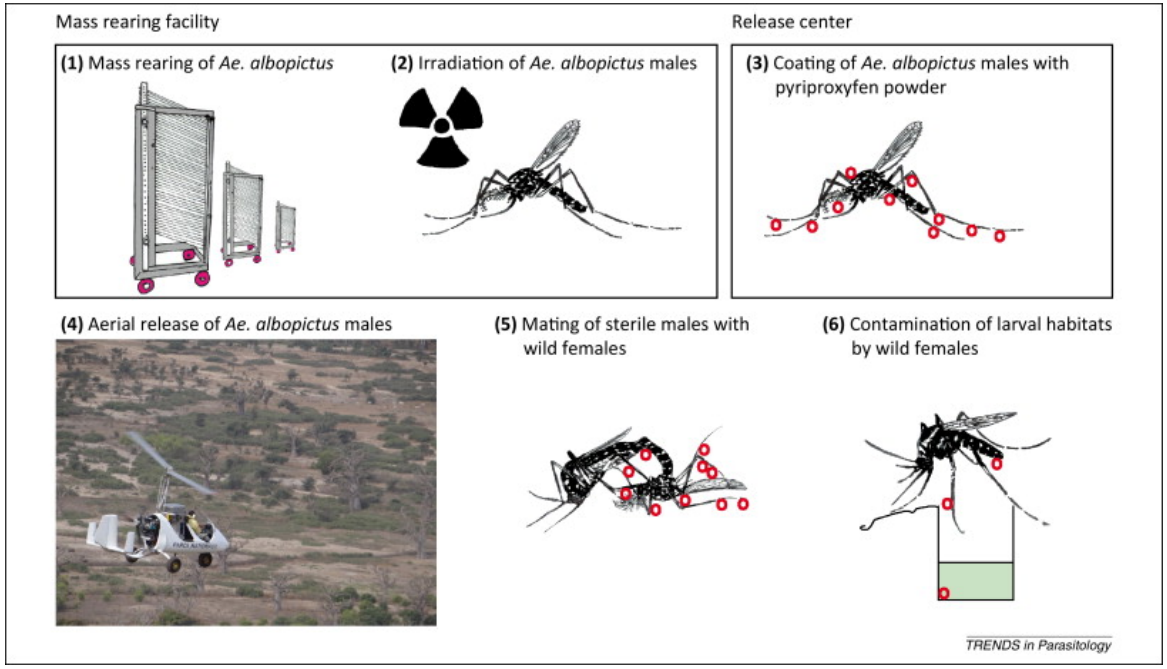
Mating harassment may boost the effectiveness of the sterile insect technique for *Aedes* mosquitoes

Received: 21 July 2023

Accepted: 20 February 2024

Dongjing Zhang[1,14], Hamidou Maiga[2,3,14], Yongjun Li[4,5,14], Mame Thierno Bakhoum[3,6,14], Gang Wang[1,14], Yan Sun[1], David Damiens[7], Wadaka Mamaï[2], Nanwintoum Séverin Bimbilé Somda[2,8], Thomas Wallner[2], artina[2], Simran Singh Kotla[2], Hanano Yamada[2], , Jiatian Guo[1], Qingdeng Feng[1], Junyan Zhang[1], [1], Wenjie Pan[10], Yu Wu[1], Xiaoying Zheng[1], , Marc J. B. Vreysen[2] & Jérémy Bouyer[2,12,13,14]

Boosted SIT





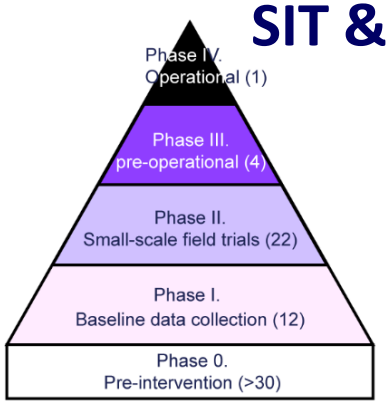

Pyriproxyfen

(Bouyer & Lefrançois, 2014)

erc European Research Council

REVOLINC

SIT & IIT-SIT & Boosted SIT: ONGOING AND PAST TRIALS (2024)



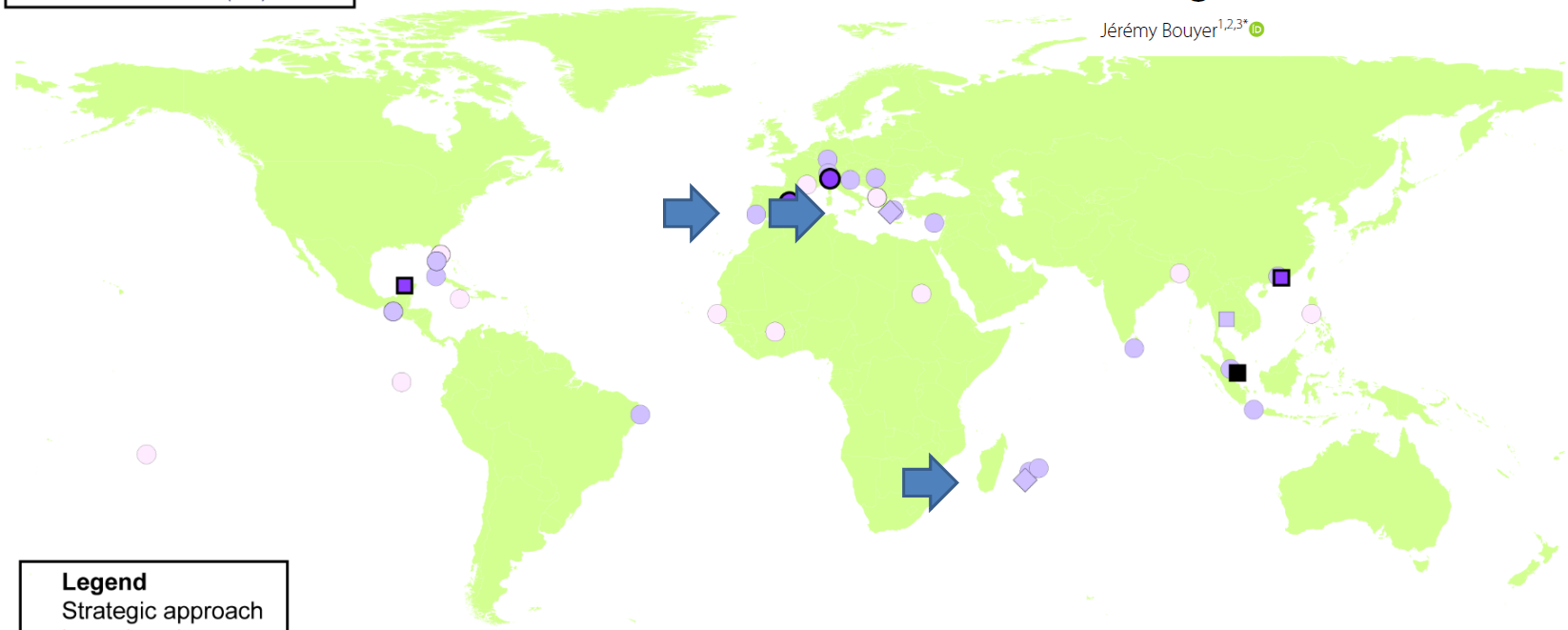
Bouyer *Infectious Diseases of Poverty* (2024) 13:68
https://doi.org/10.1186/s40249-024-01242-z

Infectious Diseases of Poverty

COMMENTARY Open Access

Current status of the sterile insect technique for the suppression of mosquito populations on a global scale

Jérémy Bouyer[1,2,3*]



Legend
Strategic approach in testing sites
- ■ IIT-SIT (4)
- ● SIT (32)
- ◆ boosted SIT (3)

SIT & IIT-SIT & Boosted SIT: ONGOING AND PAST TRIALS (2024)

Bouyer *Infectious Diseases of Poverty* (2024) 13:68
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Infectious Diseases of Poverty

COMMENTARY Open Access

Current status of the sterile insect technique for the suppression of mosquito populations on a global scale

Jérémy Bouyer[1,2,3*]

Phase	I	II	III	IV	Total
2019	21	11	2	0	34
2024	12	22	4	1	38
Increase rate	-43%	100%	50%	100%	NA

IIT-SIT: Phase IV in Singapore

Effectiveness of *Wolbachia*-mediated sterility coupled with sterile insect technique to suppress adult *Aedes aegypti* populations in Singapore: a synthetic control study

Somya Bansal, Jue Tao Lim*, Chee-Seng Chong*, Borame Dickens*, Youming Ng, Lu Deng, Caleb Lee, Li Yun Tan, Evdoxia G Kakani, Yanni Yoong, David Du Yu, Grace Chain, Pei Ma, Shuzhen Sim, Lee Ching Ng, Cheong Huat Tan*

Lancet Planet Health 2024;
8: e617–28

"We found that *Wolbachia*-based IIT-SIT reduced wild-type female *A aegypti* populations by a mean of 62·01% (95% CI 60·68 to 63·26) by 3 months, 78·40% (77·56 to 79·18) by 6 months, and **91·32% (90·95 to 91·66) by at least 18 months** of releases."

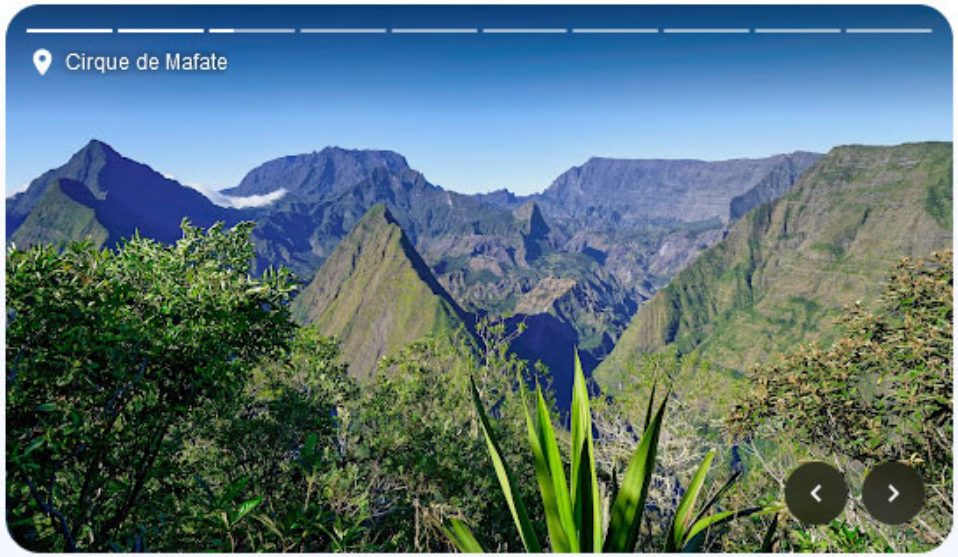
"Our study comprised an at-risk population of 607 872 individuals living in intervention sites and 3 894 544 individuals living in control sites. Interventions demonstrated up to **77·28% (121/156, 95% CI 75·81–78·58)** intervention efficacy despite incomplete coverage across all towns until EW 26, 2022."

Fonds Européen
de Développement Régional

REGION REUNION

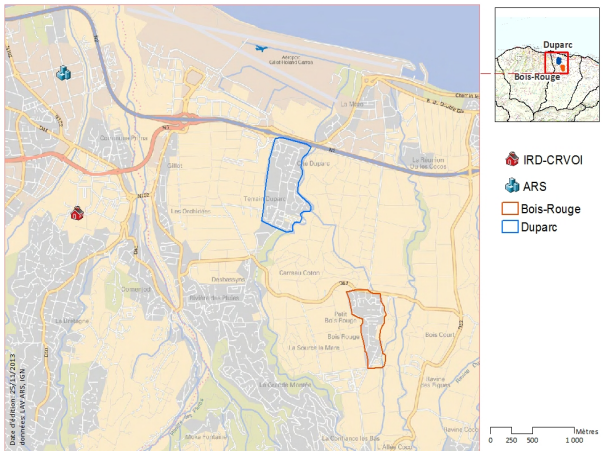
Institut de Recherche
pour le Développement
FRANCE

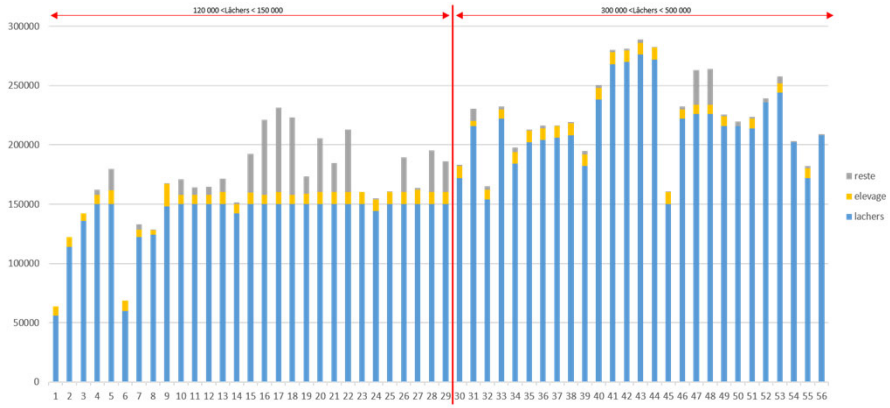
cirad



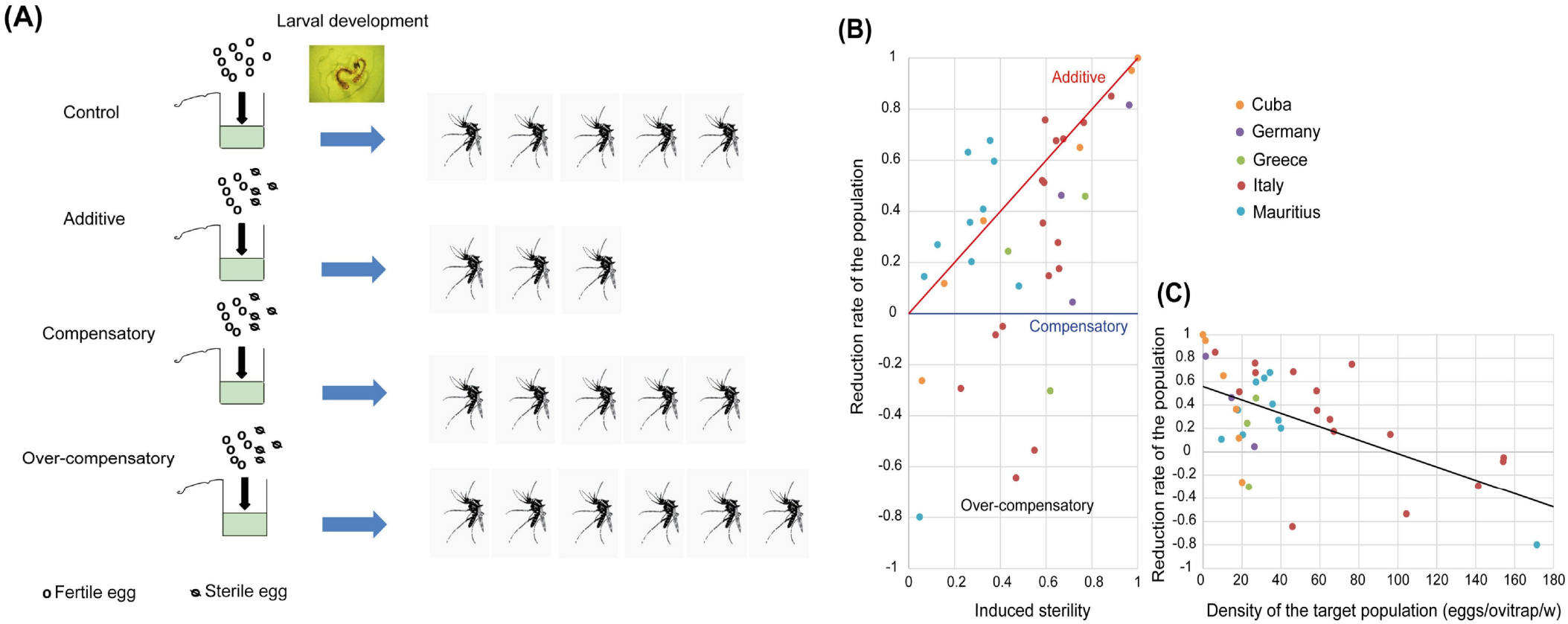
SIT in Reunion island

- Phase II trial in Sainte Marie 20 ha
- Mass-production module established (CRVOI)
- 300.000 sterile males produced / released per w in 2021
- Excellent quality of the sterile males
- Max 50% of induced sterility (target area too small & not isolated) / no reduction of adult density
- Very good acceptation by the beneficiary population





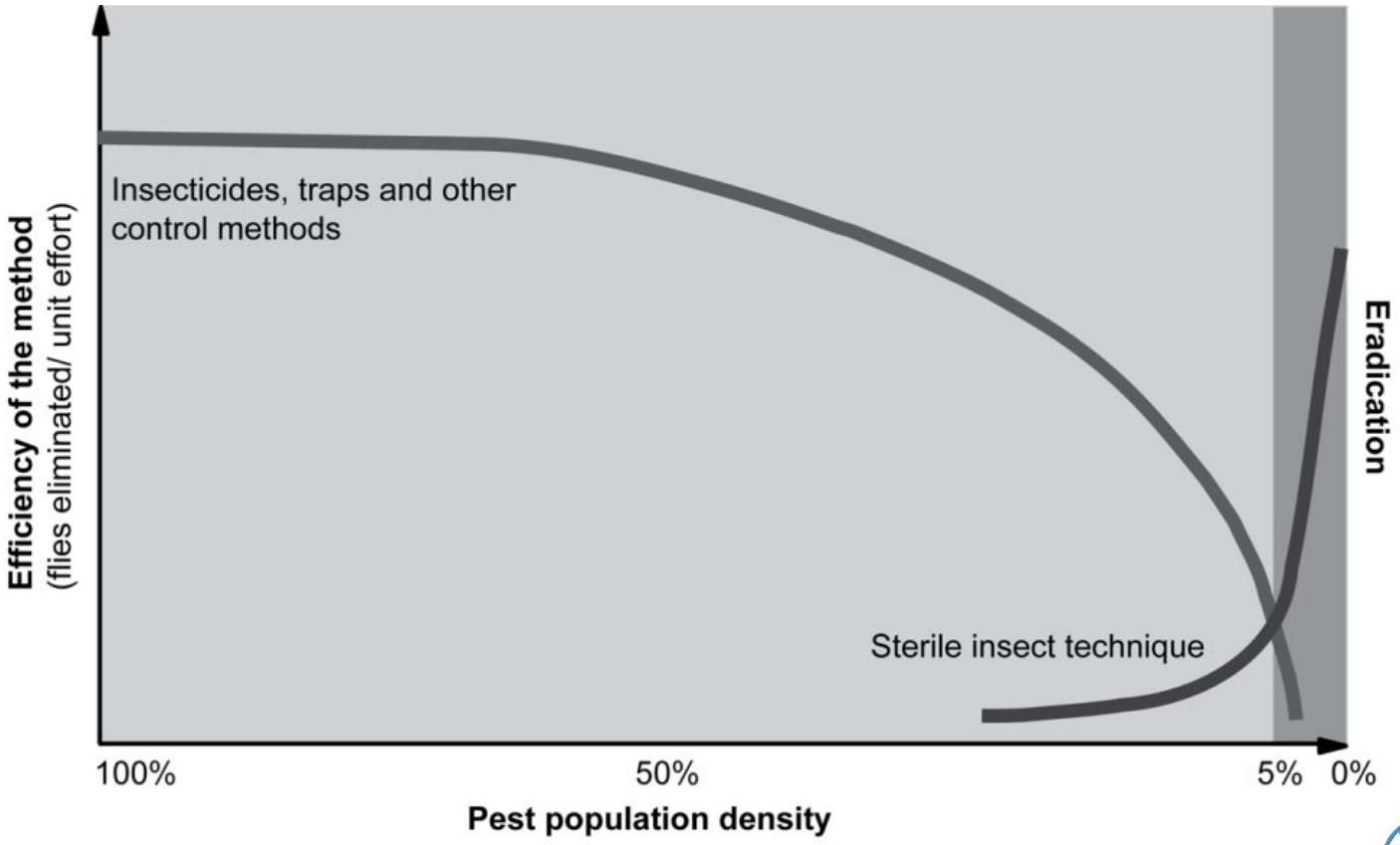
Beware of (over)-compensation!



Trends in Parasitology DOI: (10.1016/j.pt.2023.02.001)

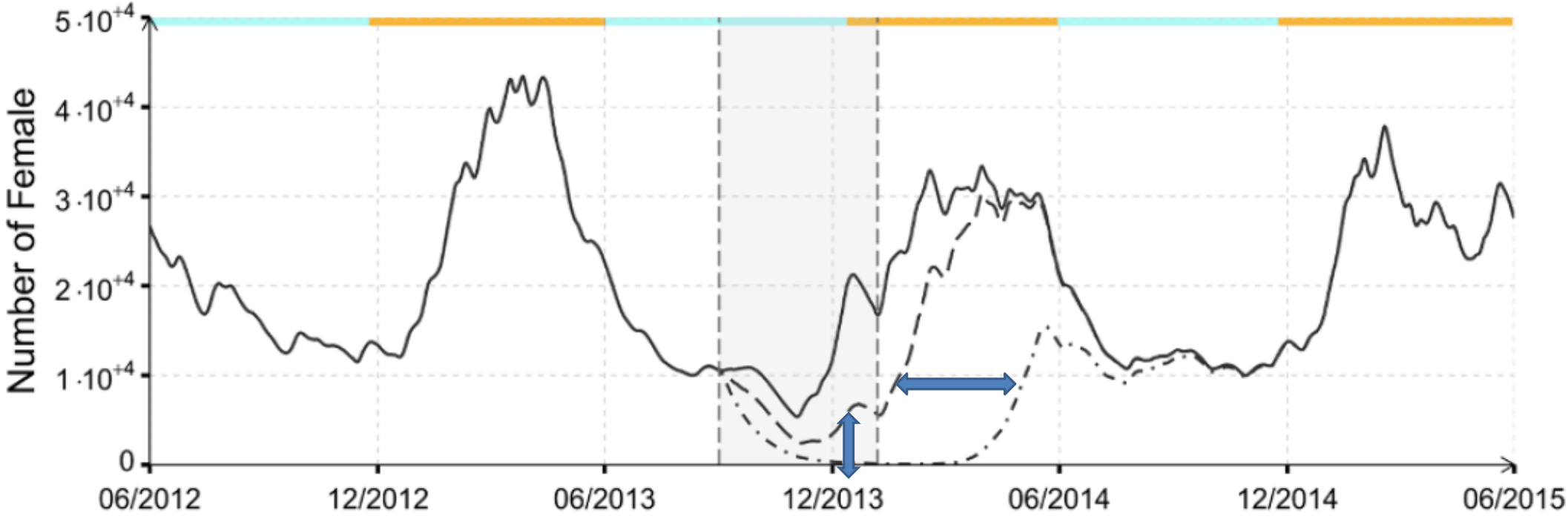
Cell PRESS Trends in Parasitology

Value of SIT in AW-IPM strategies



Joint FAO/IAEA Centre
Nuclear Techniques in Food and Agriculture

Model predictions



Better suppression & resilience than SIT

Haramboure et al. (2020) Ecological Modelling 424: 109002

Boosted SIT phase II trials

Aedes aegypti (Reunion)

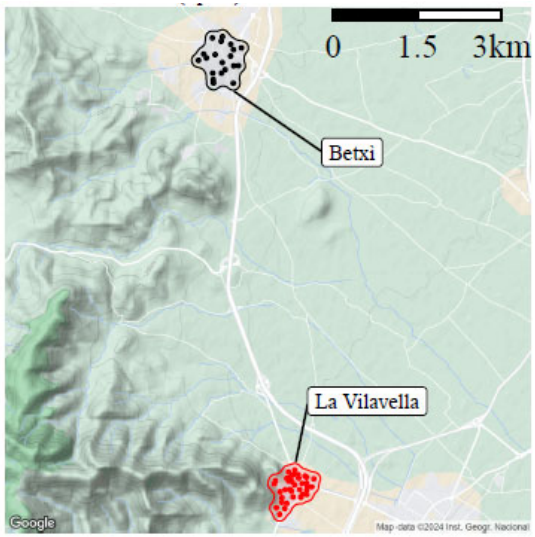
St Joseph, Réunion 10ha

>90% reduction of adult *Aedes aegypti* in 3 months

~60% reduction of adult *Aedes albopictus* & eggs in 3 months

Aedes albopictus (Spain)

Vilavella, 35ha

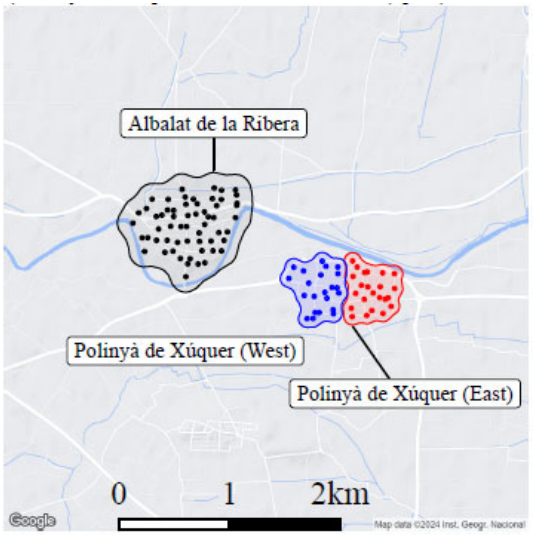


50-95% reduction of adult *Aedes albopictus*

25-60% reduction of eggs *Aedes albopictus*

14-26% increased suppression in comparison to SIT

Polinyà de Xúquer, 22ha



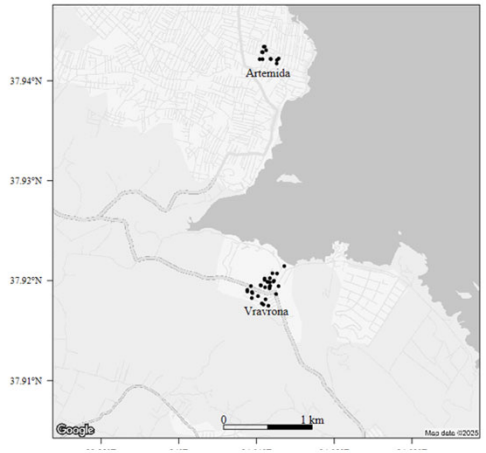
50-95% reduction of adult *Aedes albopictus*

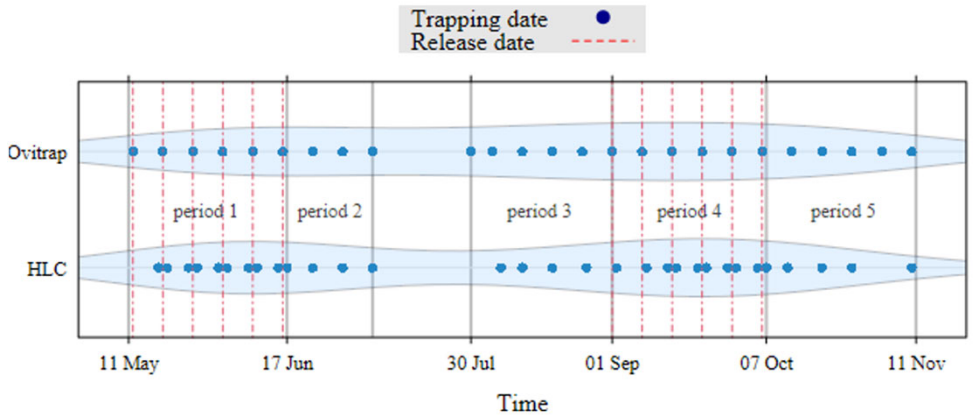
25-60% reductionof eggs *Aedes albopictus*

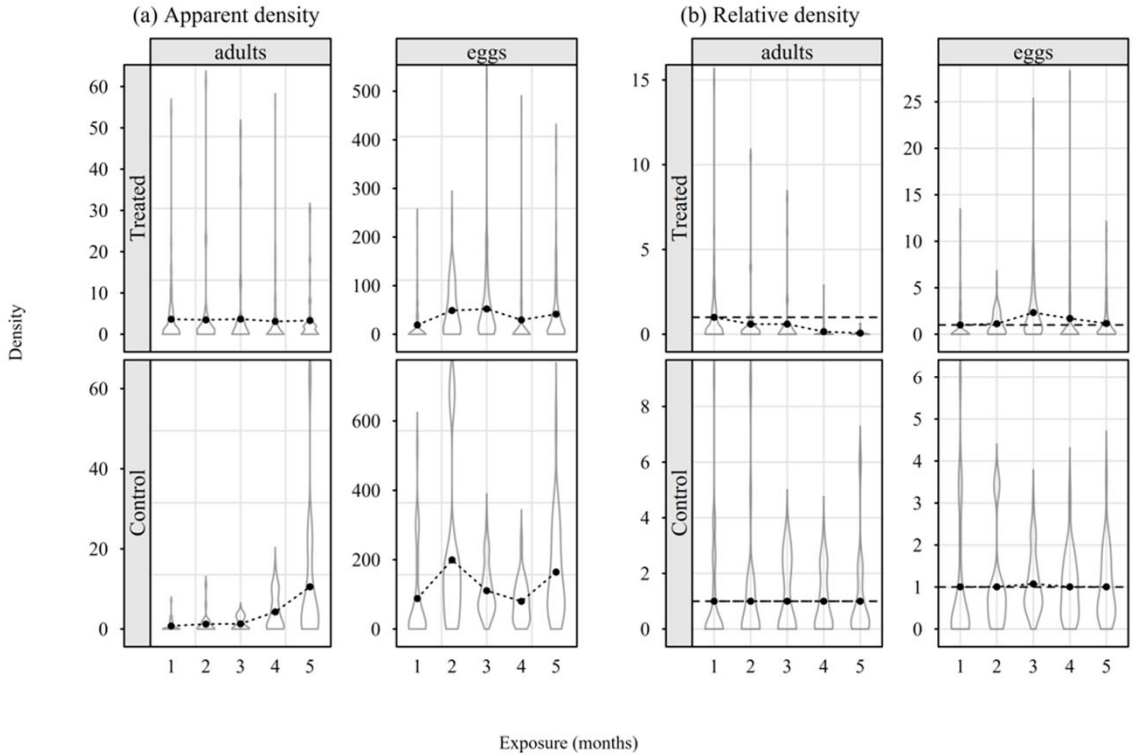
European Research Council

Boosted SIT phase II trial in Greece / intermittent releases

BENAKI PHYTOPATHOLOGICAL INSTITUTE







<8% egg population reduction in the treated site compared to the control site

Reduction of adults started 1 month after the first cycle of release (40%), reached 85-93% during the second cycle and for one month

Giatropoulos et al. 2025 Suppression of *Aedes albopictus* (Diptera: Culicidae) populations using a boosted sterile insect technique in Greece, in prep.

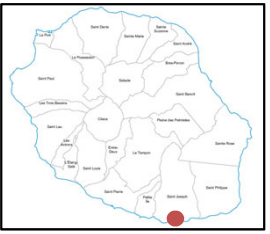
Main results of boosted SIT trials in Europe (phase II)

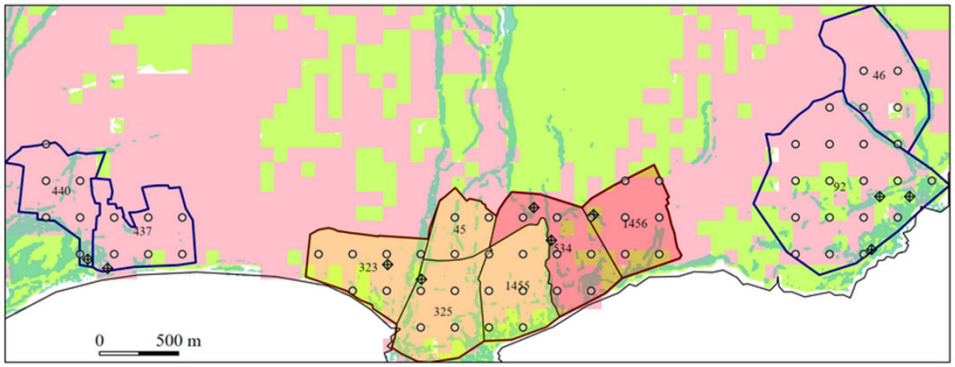
- More efficient than SIT, but not as much as predicted in Spain (large larval habitats?)
- Partially protects against “eggs immigration”
- Prevents compensation & overcompensation
- Persistent effect
- Perfect combination with SIT
- No observed environmental impact (bees & chironomides in Reunion)
- Excellent acceptation by beneficiary populations

Perspectives

pTIS

Phase III trial in Reunion 2025-26





Saint Joseph

OBJECTIVES

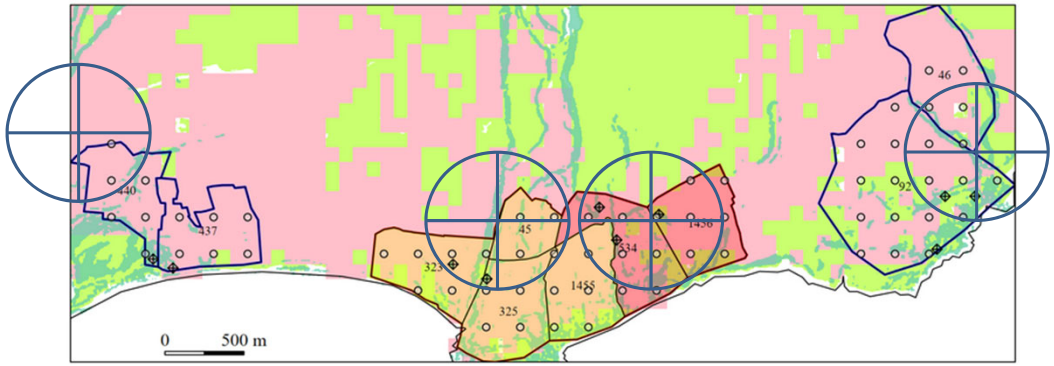
- ➔ Sequential upscale 50->175ha conditional to success & acceptability
- ➔ Efficiency on *Ae. albopictus* & *Ae. aegypti*
- ➔ Environmental impact (water, chironomides & other NTOs, bees)
- ➔ Impact on vector-host contact & dengue incidence
- ➔ Economical model with transfer to a local start-up

Suivi environnemental

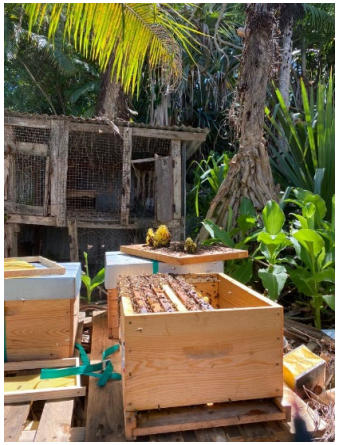
4 ruchers avec 10 ruches par site avec suivi de la santé des ruches (méthode Coleval) et mesure des résidus de pyriproxifène dans la cire, le pollen, le miel et les abeilles tous les 3 mois (sous-traitance *CETA*)

Suivi de 15 gîtes larvaires par zone (10 naturels et 5 anthropiques):

- dosage du pyriproxifène dans l'eau des gîtes larvaires
- Faune non-cible de ces gîtes caractérisée tous les mois (taxonomie & eDNA)
- Faune non-cible comptabilisé dans les pièges à adultes (bycatch)



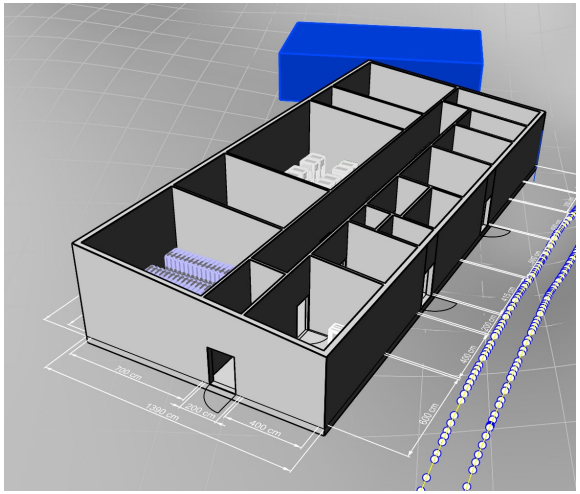
Localisation des ruchers sentinelles et aires de récolte des abeilles



Creation of a start-up spin-off from Cirad in Sept. 2023

Mosquito control service
(450-2000€/ha/y)

- Corporates (hotels, islands)
- Municipalities (schools, hospitals)



Demande d'opérationnalisation accélérée par 4 mairies de la Réunion suite à l'épidémie de chikungunya

Etude de faisabilité en cours pour une usine avec une capacité de 2-2,5 millions de mâles stériles à St Joseph

Utilisation hétérospécifique de la TIS boostée pour prévenir les invasions

Trends in Parasitology

CellPress

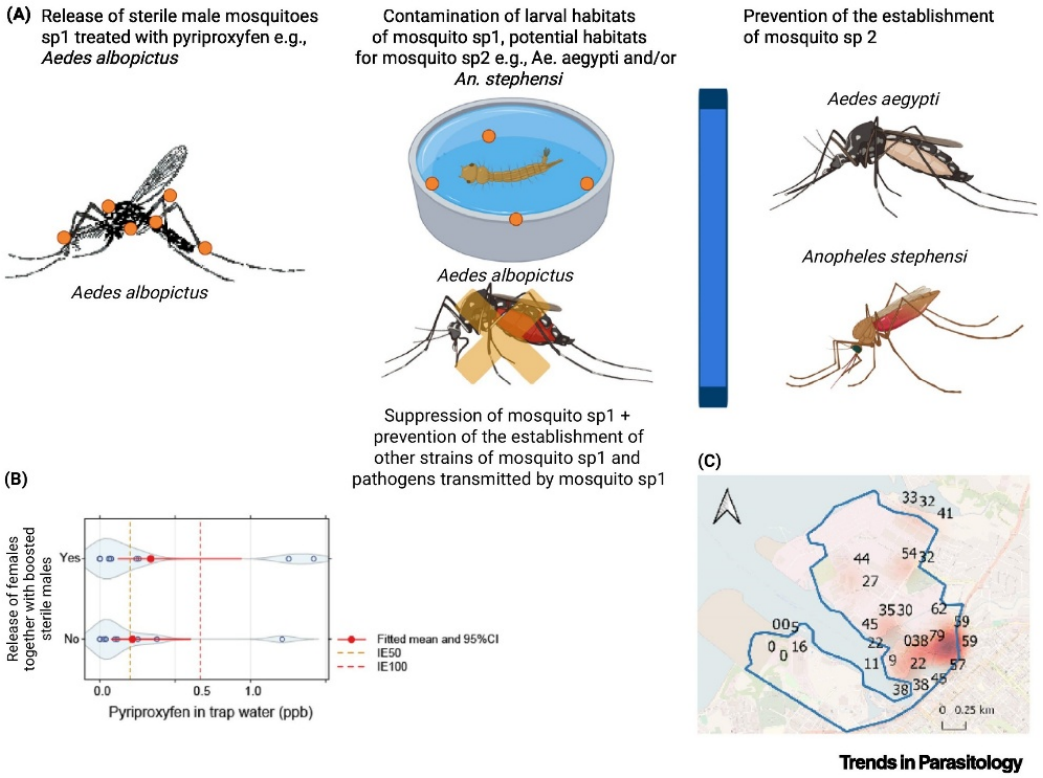
Available online 21 June 2025

In Press, Corrected Proof What's this?

Forum

Preventing the establishment of invasive exotic mosquitoes

Jérémy Bouyer [1 2 3], Diana Iyaloo [4], Thierry Baldet [1 2]



Merci!

Fonds Européen de Développement Régional

MINISTÈRE DE L'ENSEIGNEMENT SUPÉRIEUR ET DE LA RECHERCHE
Liberté
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erc European Research Council

BENAKI PHYTOPATHOLOGICAL INSTITUTE

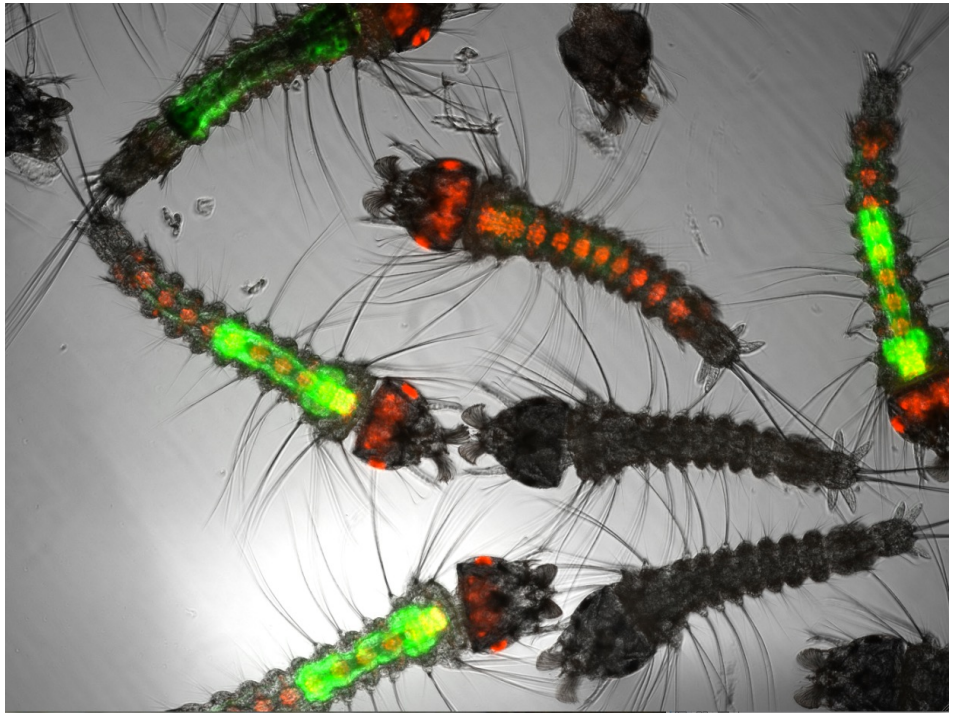
FAO FIAT PANIS IAEA Joint FAO/IAEA Centre Nuclear Techniques in Food and Agriculture

Nouvelles méthodes de LAV : techniques en phase terrain

Genetically modified mosquitoes for disease control : from conventional transgenesis… to gene drive ?

par Eric Marois

GM mosquitoes for disease control : from conventional transgenesis… to gene drive ?



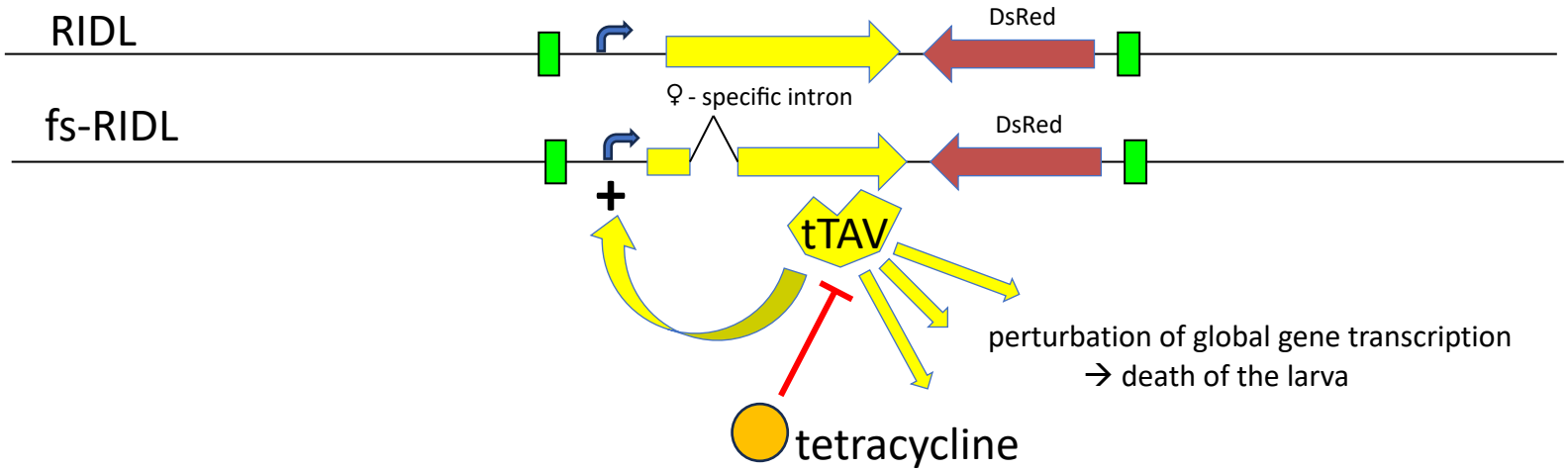
Eric Marois

Chargé de Recherches Inserm

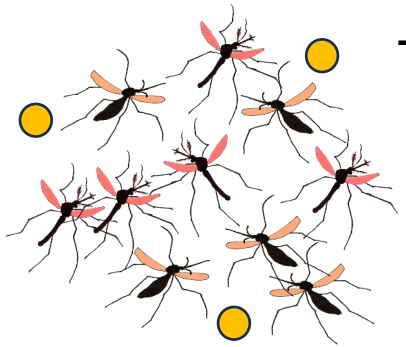
Institut de Biologie Moléculaire et Cellulaire du CNRS, Strasbourg

Oxitec : RIDL and fs-RIDL technologies

Release of Insects carrying a female-specific Dominant Lethal gene

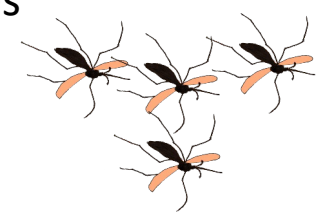


Mass-produce
with tetracycline



→ Release eggs

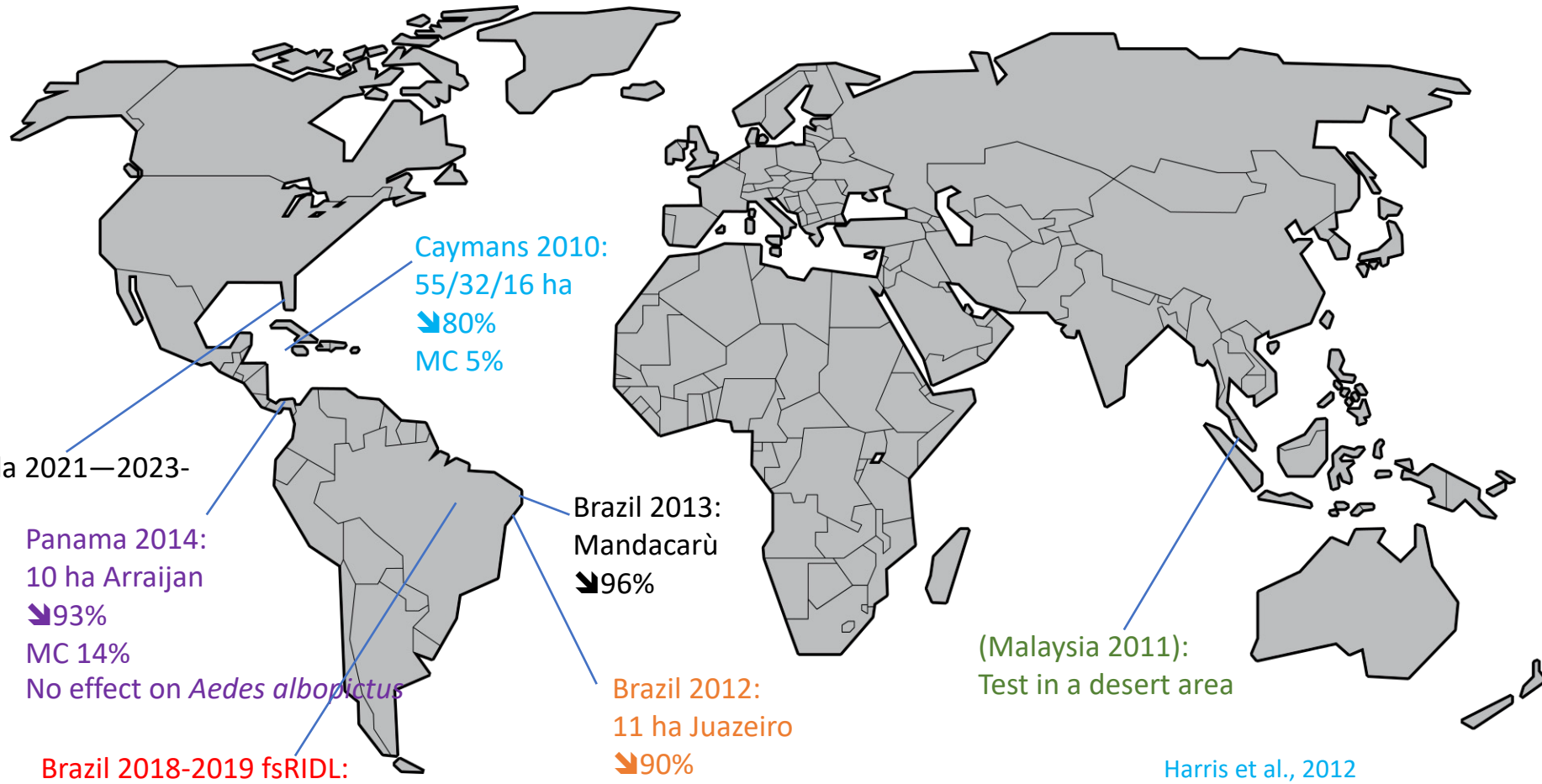
→ females die, sterile males mate with wild females



→ Daughters die ; sons transmit gene again to 50% progeny

→ Population suppression

Oxitec interventions



Caymans 2010:
55/32/16 ha
↘80%
MC 5%

Florida 2021—2023-

Panama 2014:
10 ha Arraijan
↘93%
MC 14%
No effect on *Aedes albopictus*

Brazil 2013:
Mandacarù
↘96%

Brazil 2012:
11 ha Juazeiro
↘90%
MC 3%

Brazil 2018-2019 fsRIDL:
↘72-81% 4 week average
peak 78-96%

(Malaysia 2011):
Test in a desert area

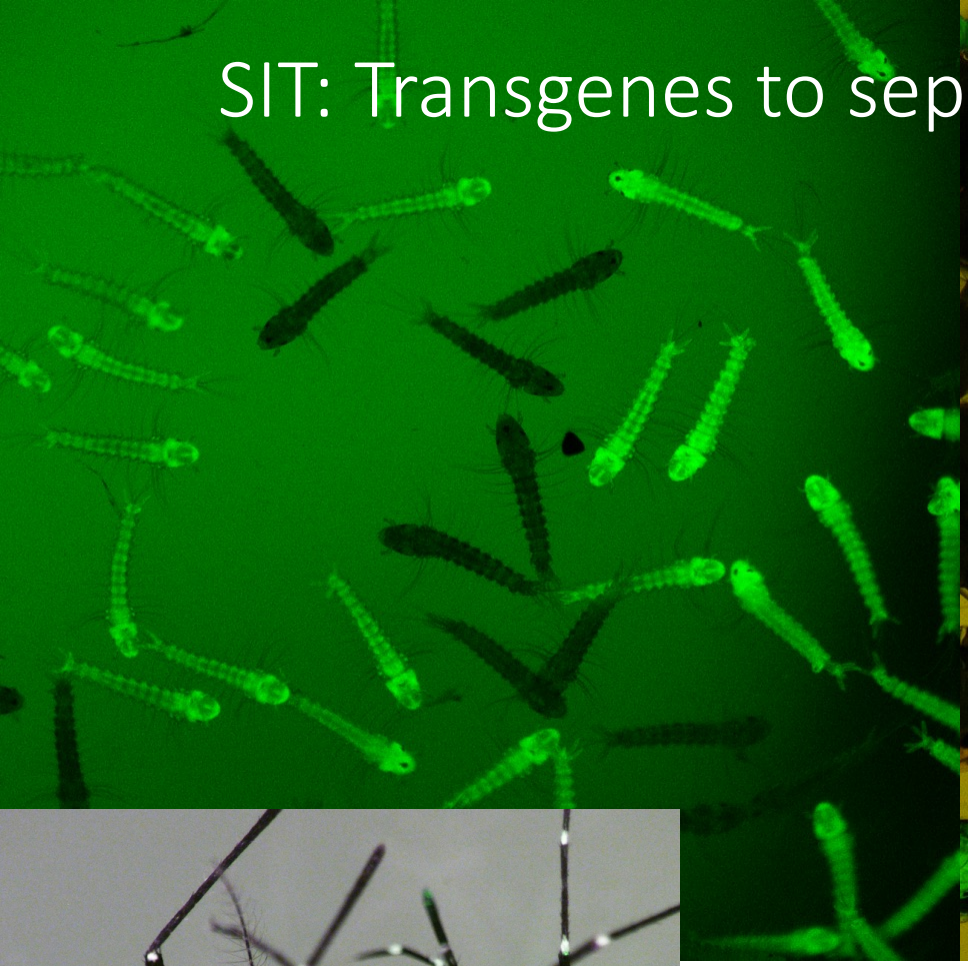
Harris et al., 2012
Lacroix et al., 2012
Carvalho et al., 2015
Gorman et al., 2016
Spinner et al., 2022

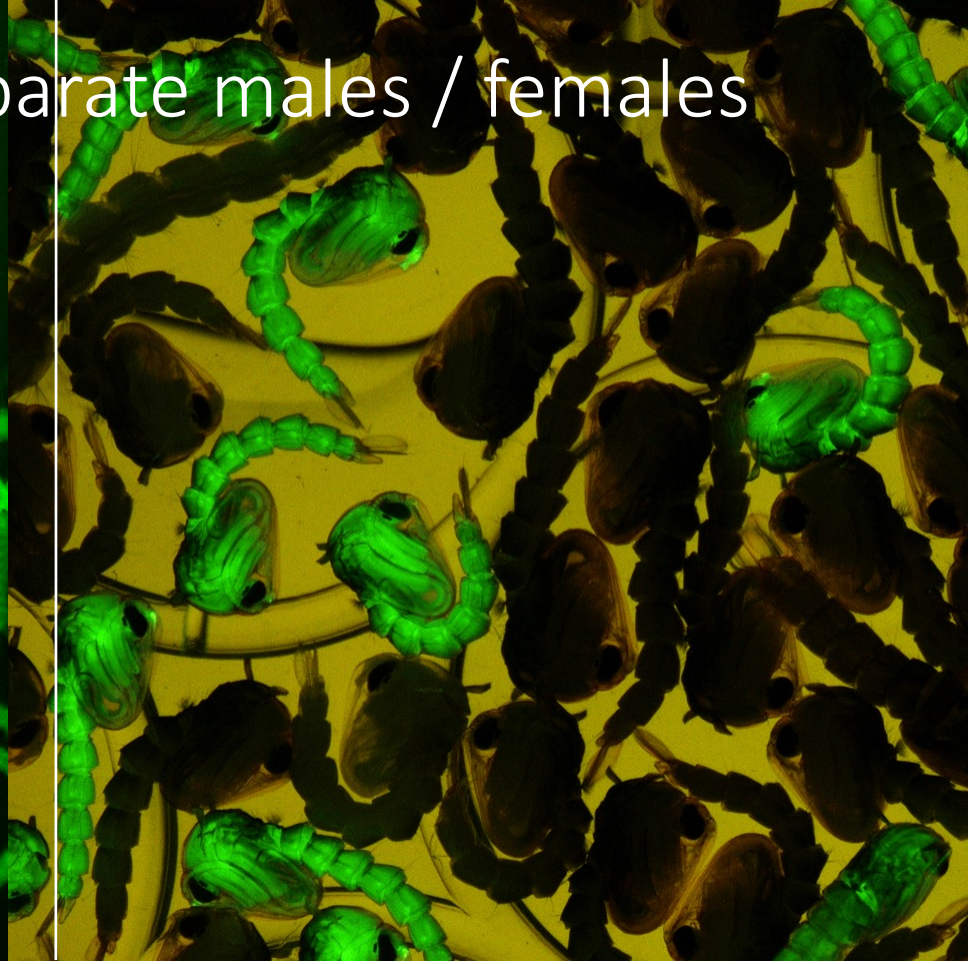
RIDL and fs-RIDL Oxitec technologies

Advantages & drawbacks

- Species-specific
- Self-dissemination
- Circumvents insecticide resistance
- No need for irradiation ≠ SIT
- No need for sex separation in fs-RIDL ≠ SIT
- Self-limiting
- Costly, complex logistics (less with fs-RIDL)
  → field trials rather than full-blown interventions
- Small spatial scale
- Not long-lasting
- Public reluctance on GM, depending on countries

SIT: Transgenes to separate males / females



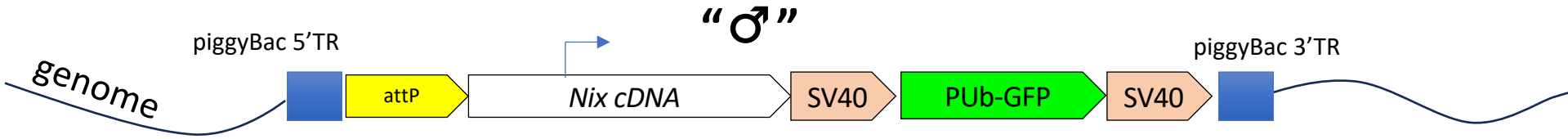


→ COPAS sorting of young larvae
→ irradiation
→ Sterile Insect Technique

(Lutrat et al., 2022, 2023)

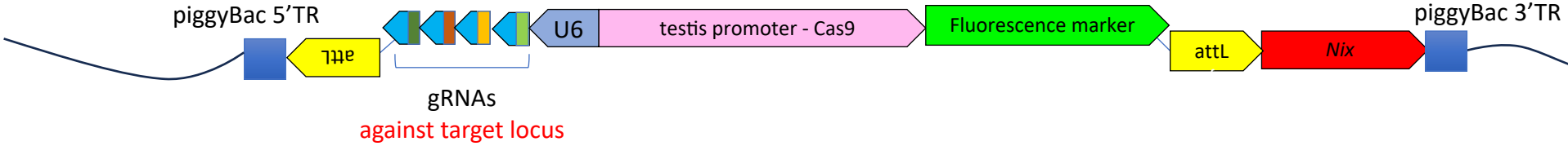
Nix-expressing transgenes are sufficient to convert females into males

Célia Lutrat
et al. Comm Biology
2022, 2023

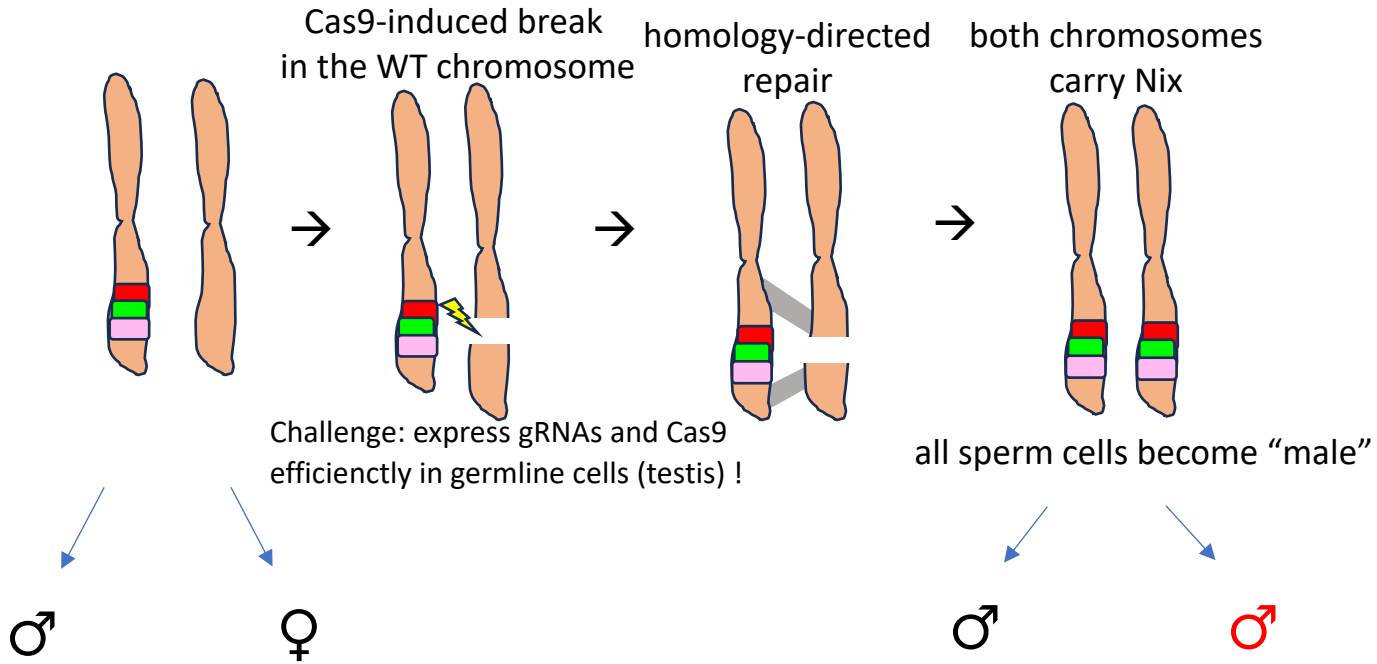


Plan A (most radical) : Maleness gene drives

Dock genes encoding the CRISPR-Cas9 system into synthetic M loci :



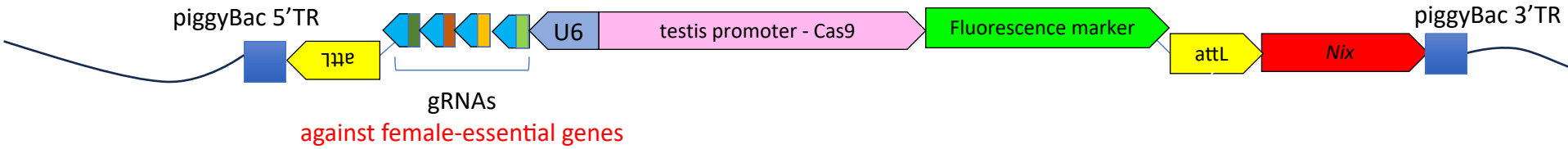
In spermatogonia, chromosome pair with heterozygous *Nix* transgene:



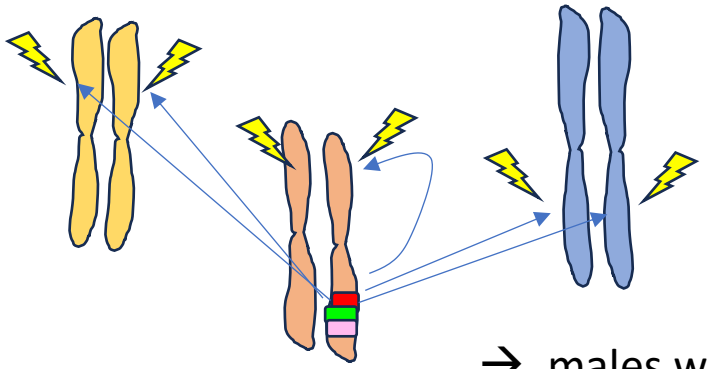
A pseudomale siring only pseudosons
= self-sustaining, masculinizing gene drive !

Plan B (less radical): M-linked editors

Dock genes encoding the CRISPR-Cas9 system into synthetic M loci :



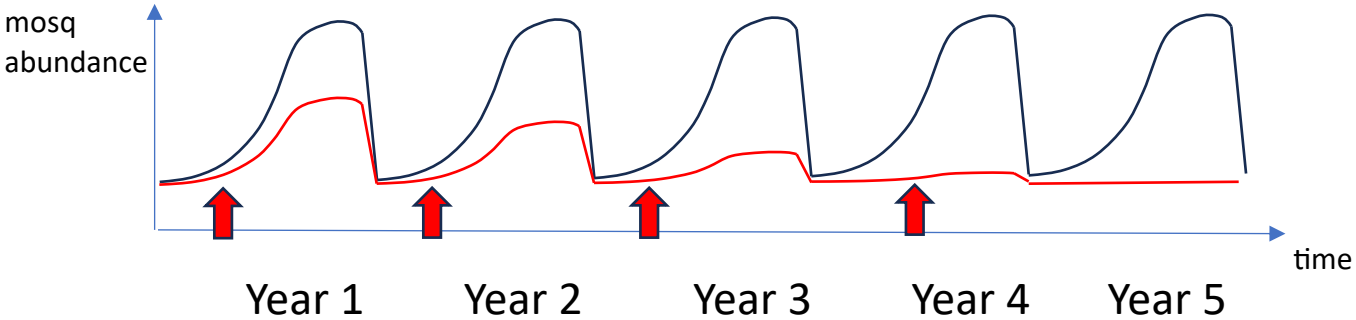
→ YLE (Y-linked editors) (Burt & Deredec, 2018) → MLE:



NHEJ –induced mutations in female-essential genes

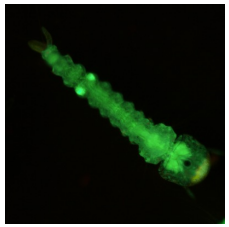
→ males whose daughters are non-flying or sterile

Mathematical modeling : not self-sustaining, but more efficient than SIT or fsRIDL

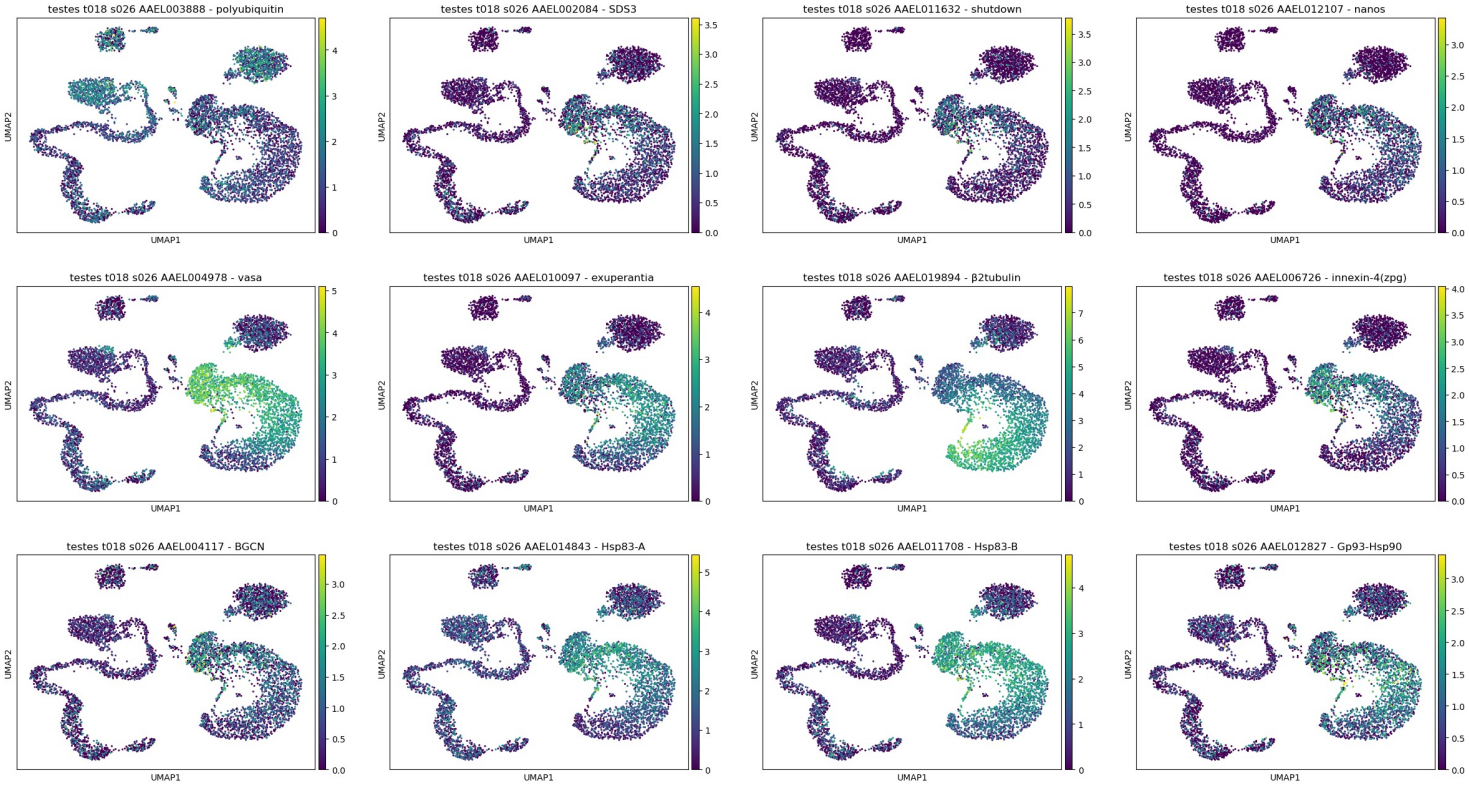


Now get CRISPR/Cas9 to work **efficiently** in *albopictus*

- clone better germline promoters to express Cas9

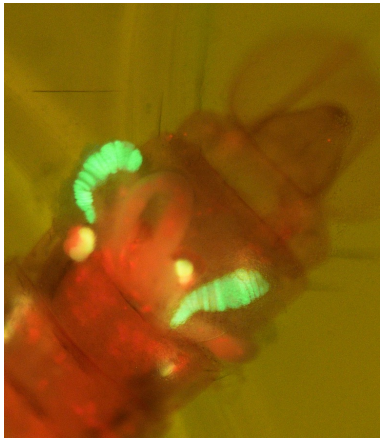


- Find the best expression system for multiplex gRNAs



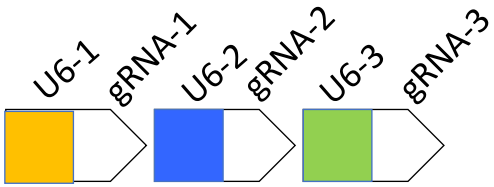
Technology development:
test promoters to optimize Cas9 and gRNA expression

candidate promoter-Cas9 lines



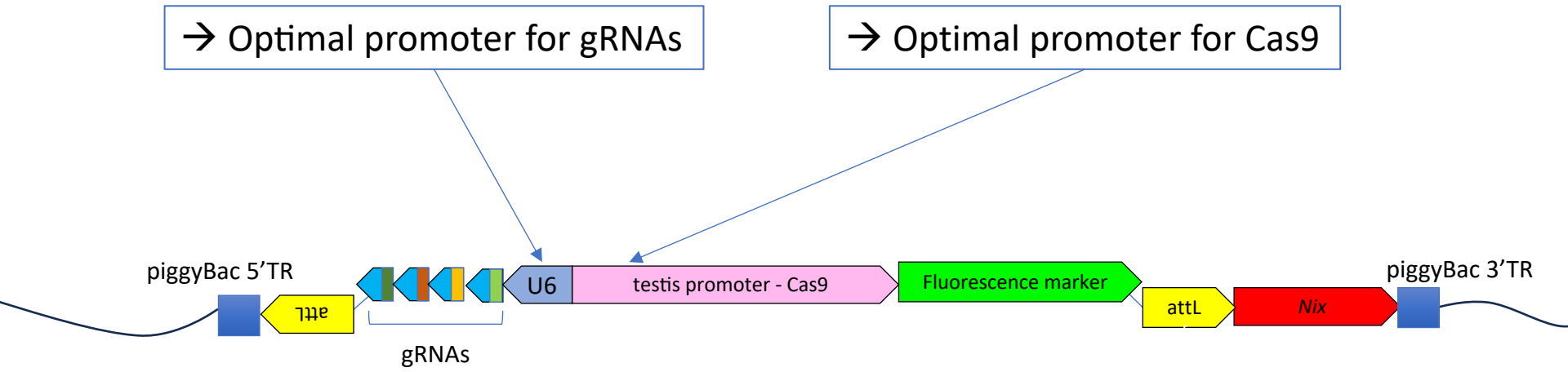
X

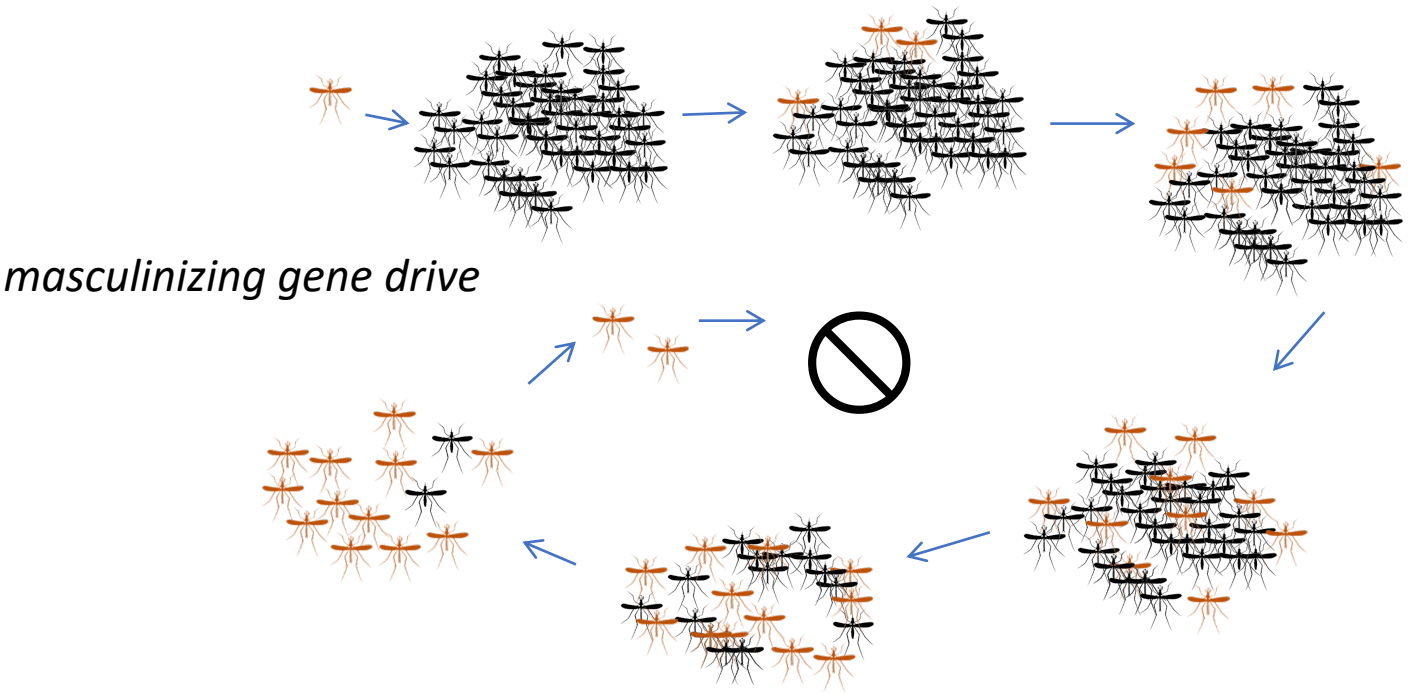
line expressing 3 gRNAs targeting yellow



→ F1 : mutagenesis of *yellow* in the germ line
x *yellow* mutant

→ F2: count the proportion of *yellow*


→ Optimal promoter for gRNAs
→ Optimal promoter for Cas9
piggyBac 5'TR
attL
U6
testis promoter - Cas9
Fluorescence marker
attL
Nix
piggyBac 3'TR
gRNAs


masculinizing gene drive

Célia Lutrat

Julie Fimeyer

Marie Aubry

Nikola Djordjevic

Victor Redon

Mateus Berni

Lucie Souriac

Roenick P. Olmo

Amandine Gautier

Stéphanie Blandin

Phi Papathanos

Doron Zaada

Jérémy Bouyer

anr

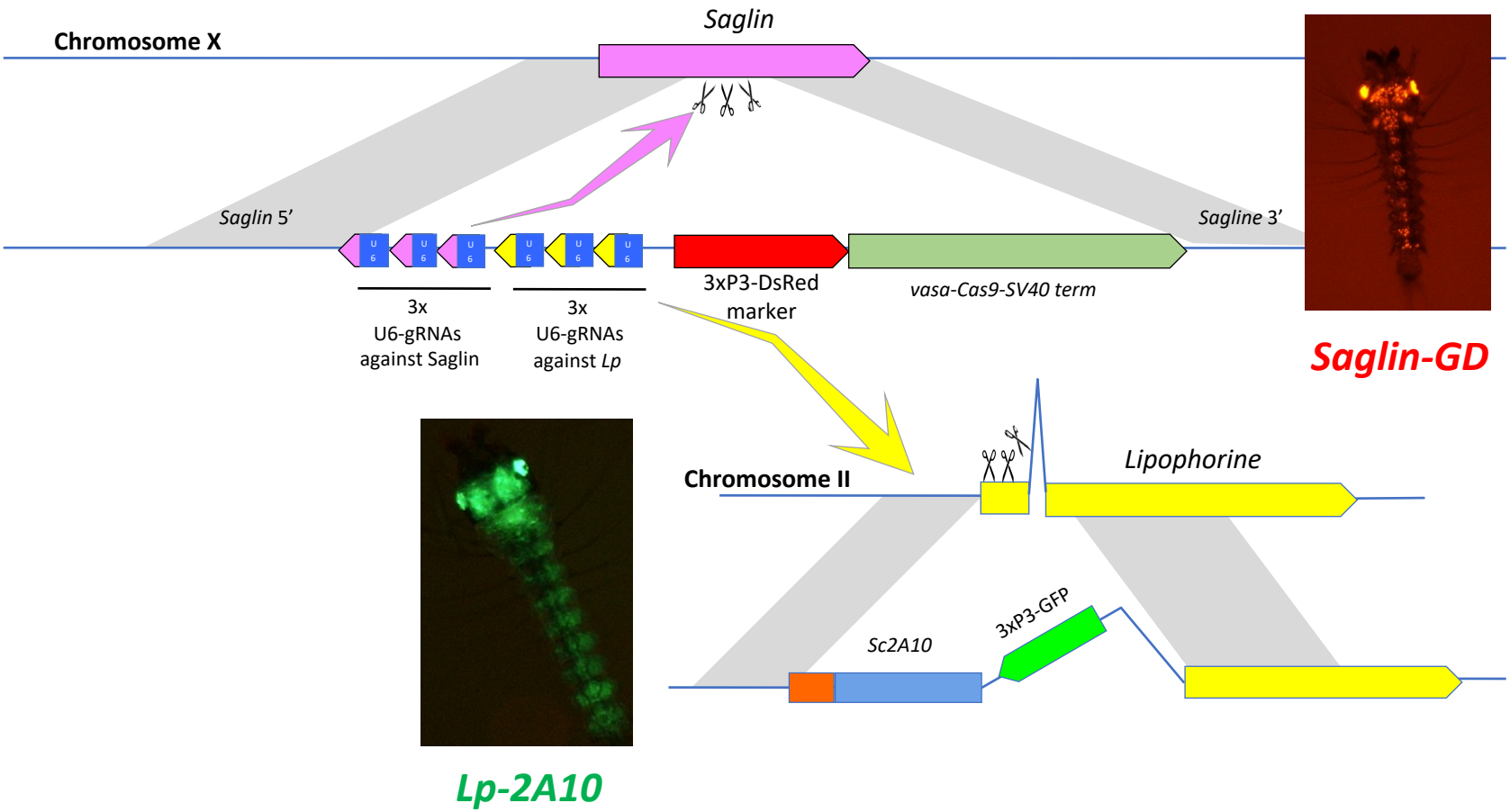
Université de Strasbourg

cnrs

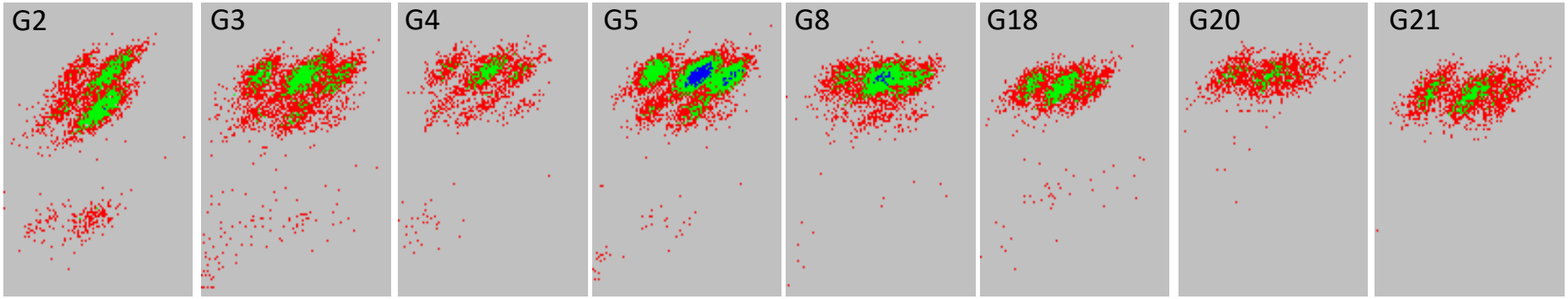
Inserm
La science pour la santé
From science to health

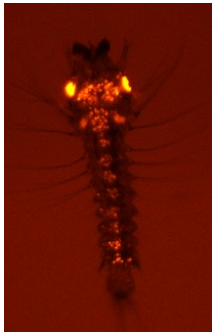
Anopheles gambiae dual *Saglin / Lipophorin* gene drive

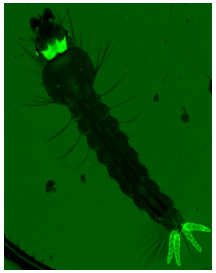
(Green et al., eLife 2024)

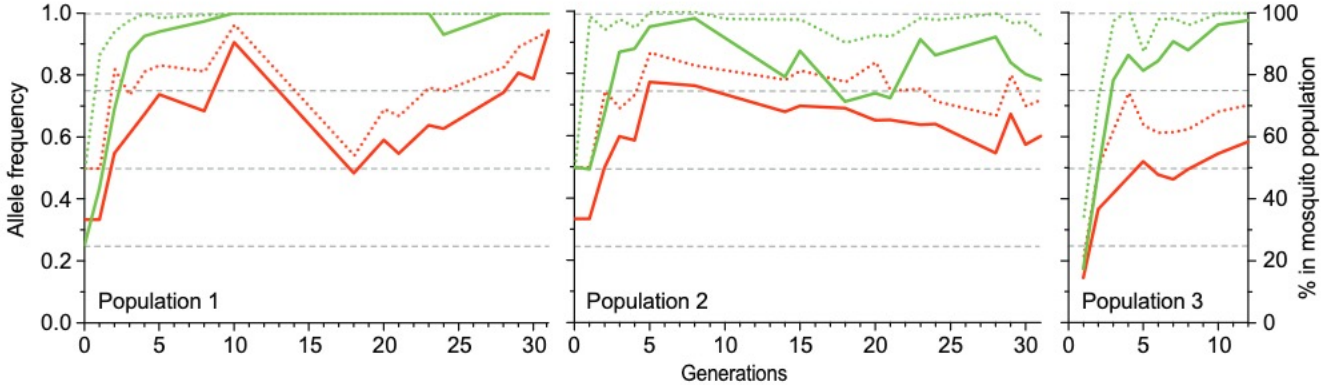


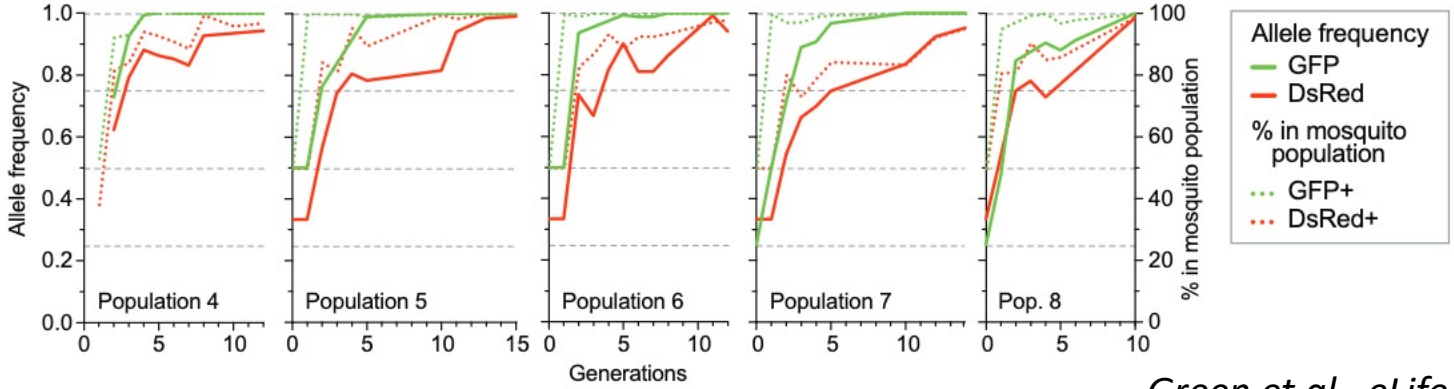
Rapid invasion by both transgenes











Green et al., eLife 2024

Nouvelles méthodes de LAV : techniques en phase terrain

Un redoutable envahisseur arrive dans les Antilles Françaises

par Anubis Vega Rua

A fearsome invader arrives in the French West Indies

Anubis Vega-Rúa
Vector-Borne Diseases Laboratory
Institut Pasteur de Guadeloupe

Colloque Arbofrance, June 23th 2025

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The French Territories of the Americas

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The French Territories of the Americas

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The French Territories of the Americas

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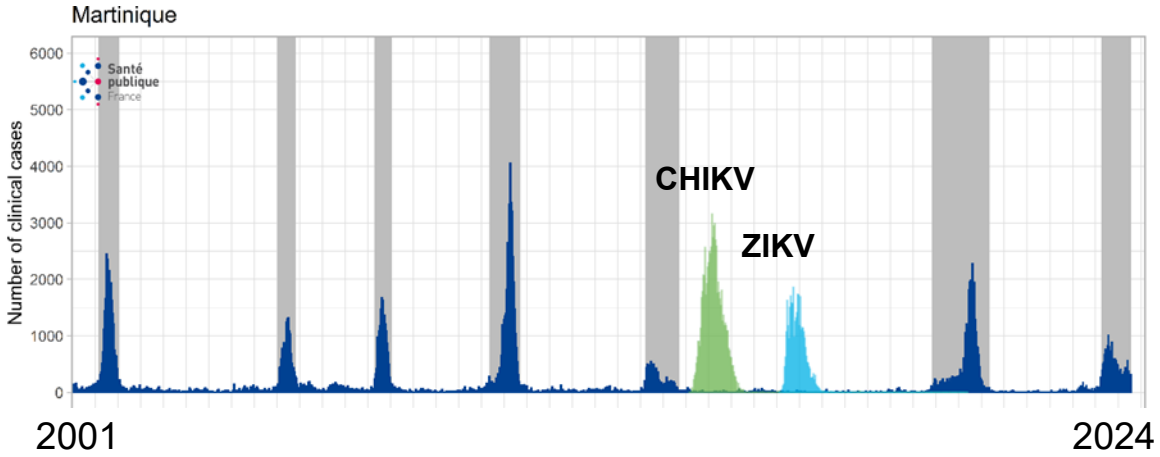

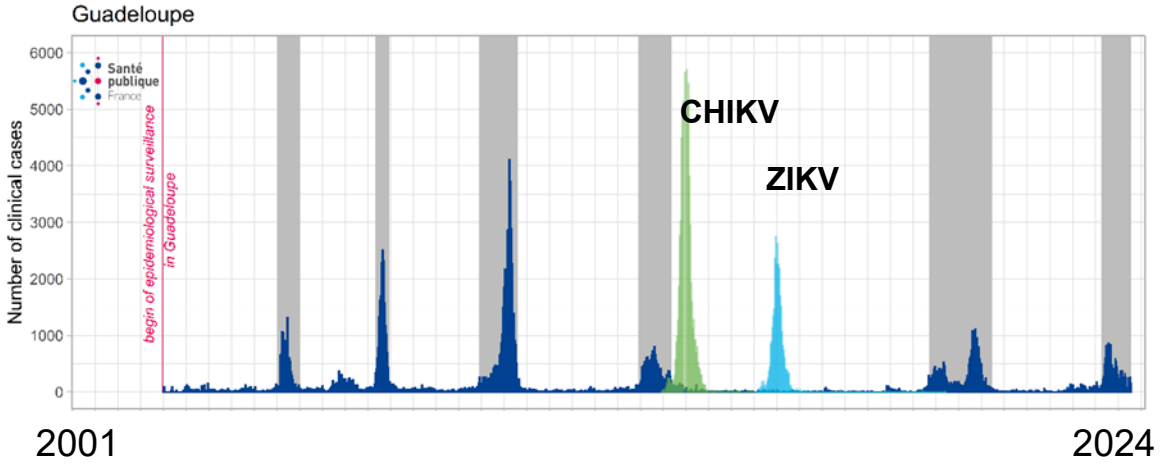

Leon et al, *In preparation*

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The French Territories of the Americas

Espèce (*Aedes* spp.)

- *Aedes aegypti*
- *Aedes albopictus*
- *Aedes polynesiensis*

bio RENDER

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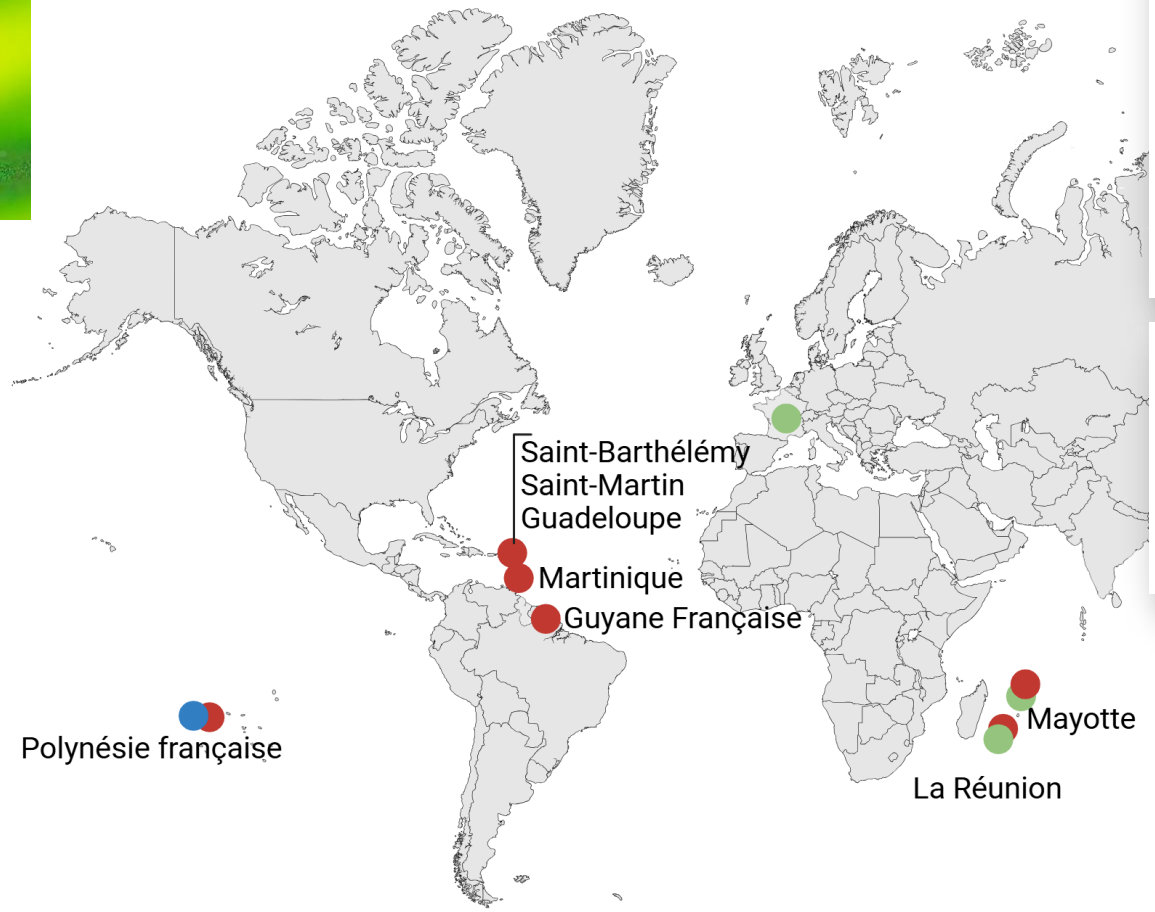
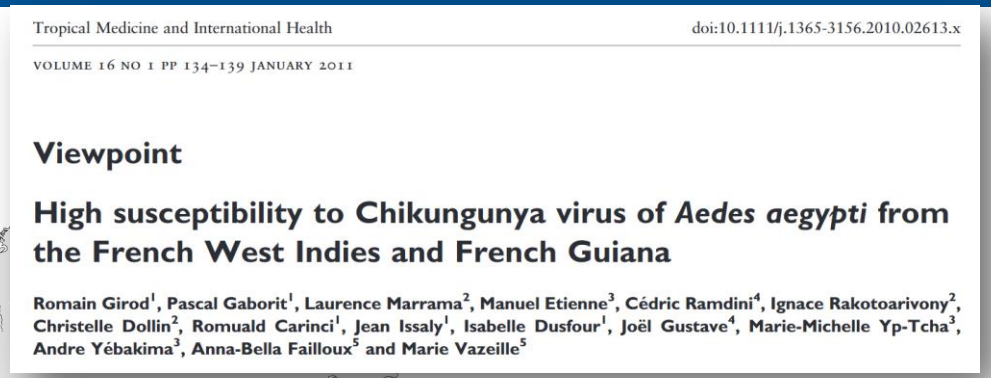
The French Territories of the Americas



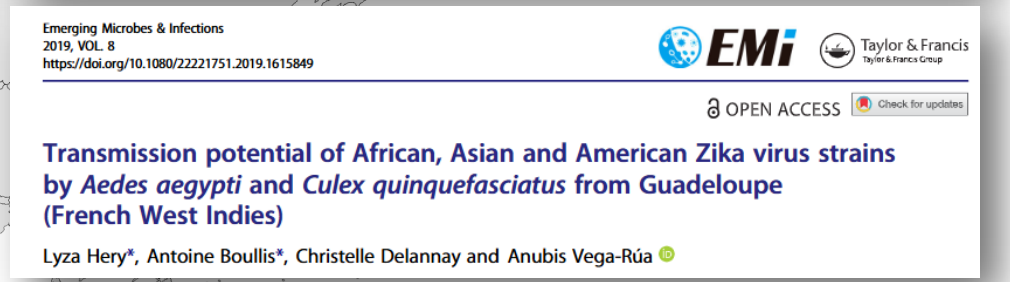


Tropical Medicine and International Health
doi:10.1111/j.1365-3156.2010.02613.x
VOLUME 16 NO 1 PP 134–139 JANUARY 2011

Viewpoint

High susceptibility to Chikungunya virus of *Aedes aegypti* from the French West Indies and French Guiana

Romain Girod[1], Pascal Gaborit[1], Laurence Marrama[2], Manuel Etienne[3], Cédric Ramdini[4], Ignace Rakotoarivony[2], Christelle Dollin[2], Romuald Carinci[1], Jean Issaly[1], Isabelle Dusfour[1], Joël Gustave[4], Marie-Michelle Yp-Tcha[3], Andre Yébakima[3], Anna-Bella Failloux[5] and Marie Vazeille[5]

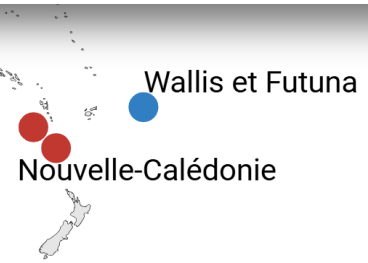


Emerging Microbes & Infections
2019, VOL. 8
https://doi.org/10.1080/22221751.2019.1615849

OPEN ACCESS

Transmission potential of African, Asian and American Zika virus strains by *Aedes aegypti* and *Culex quinquefasciatus* from Guadeloupe (French West Indies)

Lyza Hery*, Antoine Boullis*, Christelle Delannay and Anubis Vega-Rúa



Espèce (*Aedes* spp.)

- *Aedes aegypti*
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bio RENDER

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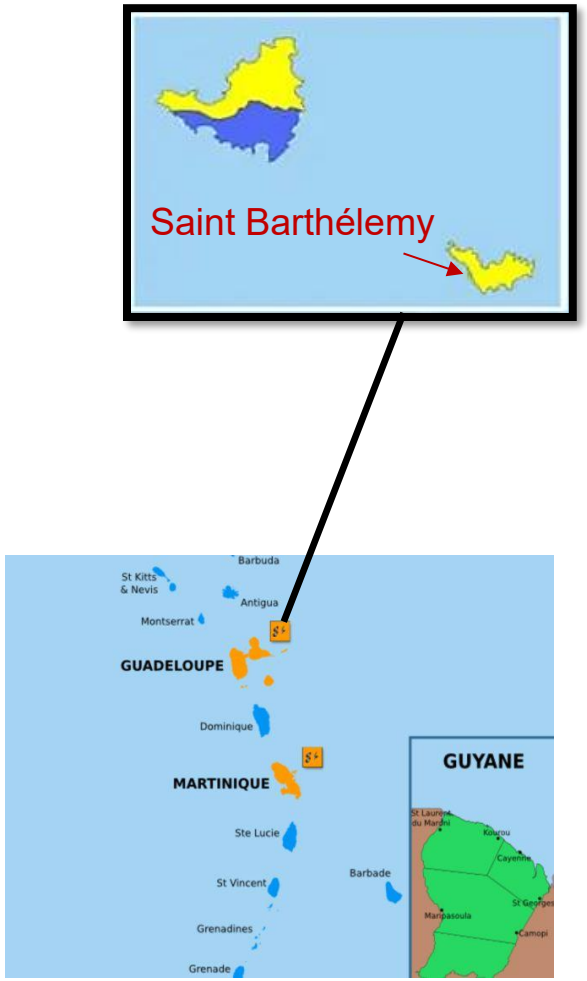
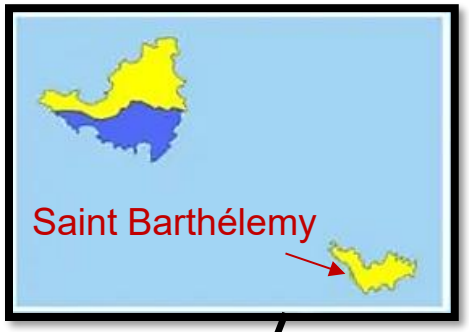
On September 30th, 2024…



Vector control agents collect mosquito larvae from a floor siphon in Saint Barthélemy

INSTITUT PASTEUR de la Guadeloupe

On September 30th, 2024…

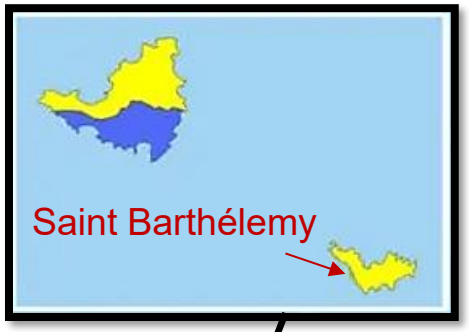


Surprise!

Strong suspicion of *Aedes albopictus*

INSTITUT PASTEUR de la Guadeloupe

On September 30th, 2024…



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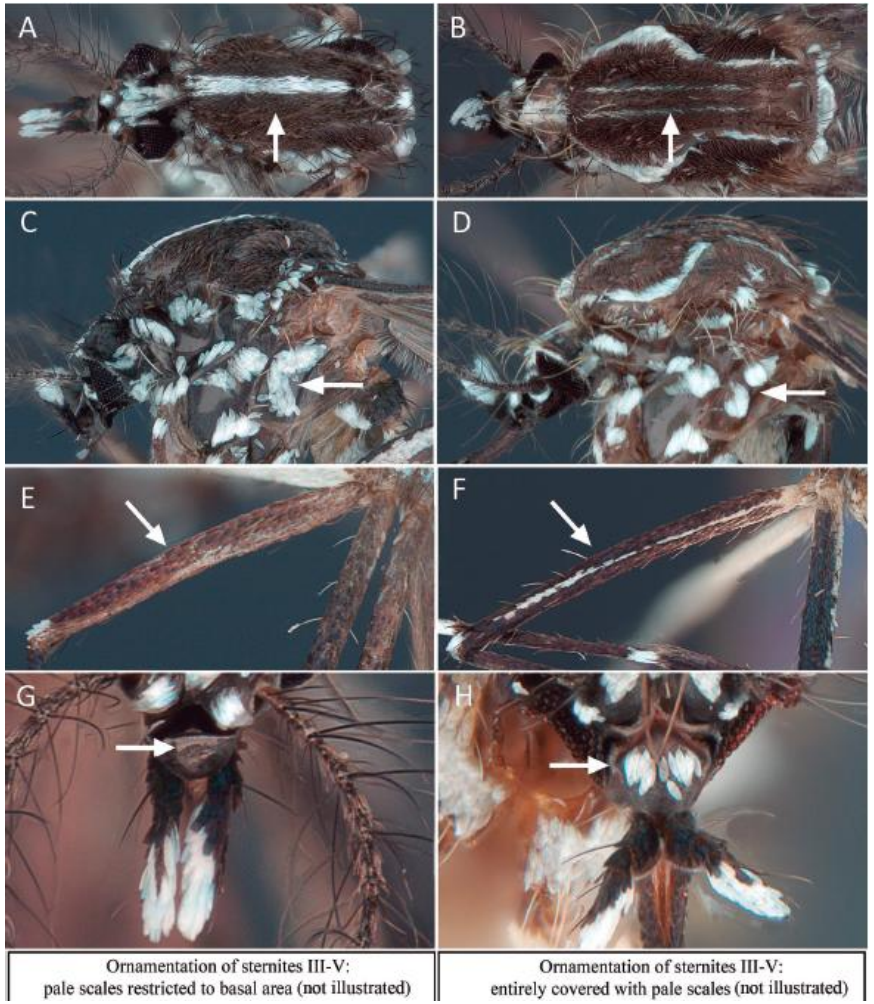

INSTITUT PASTEUR de la Guadeloupe

Mission : October 14th-16th, 2024

Objectives:

- Confirm *Ae. albopictus* identification morphologically
- Train the local agents on *Ae. albopictus* identification of diverse mosquito sampling techniques
- Event entomological monitoring
- Recover specimens to confirm identification by other approaches:
  - Matrix Assisted Laser Desorption Ionization - Time-of-Flight Mass Spectrometry (MALDI-TOF MS)
  - Cytochrome oxidase 1 (*cox1*) barcoding

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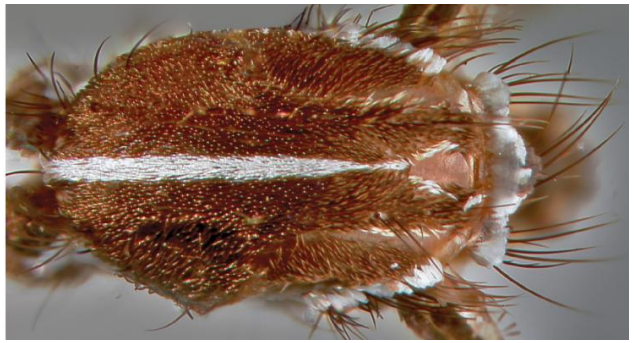
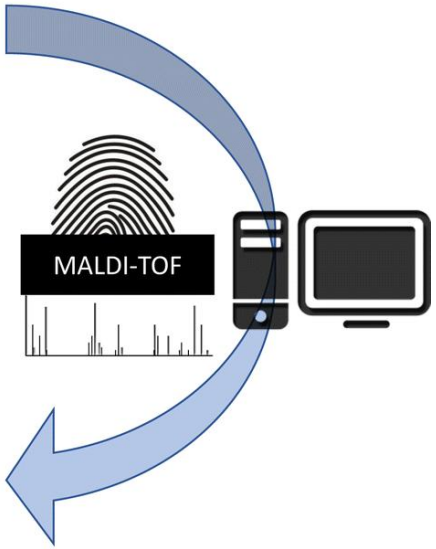


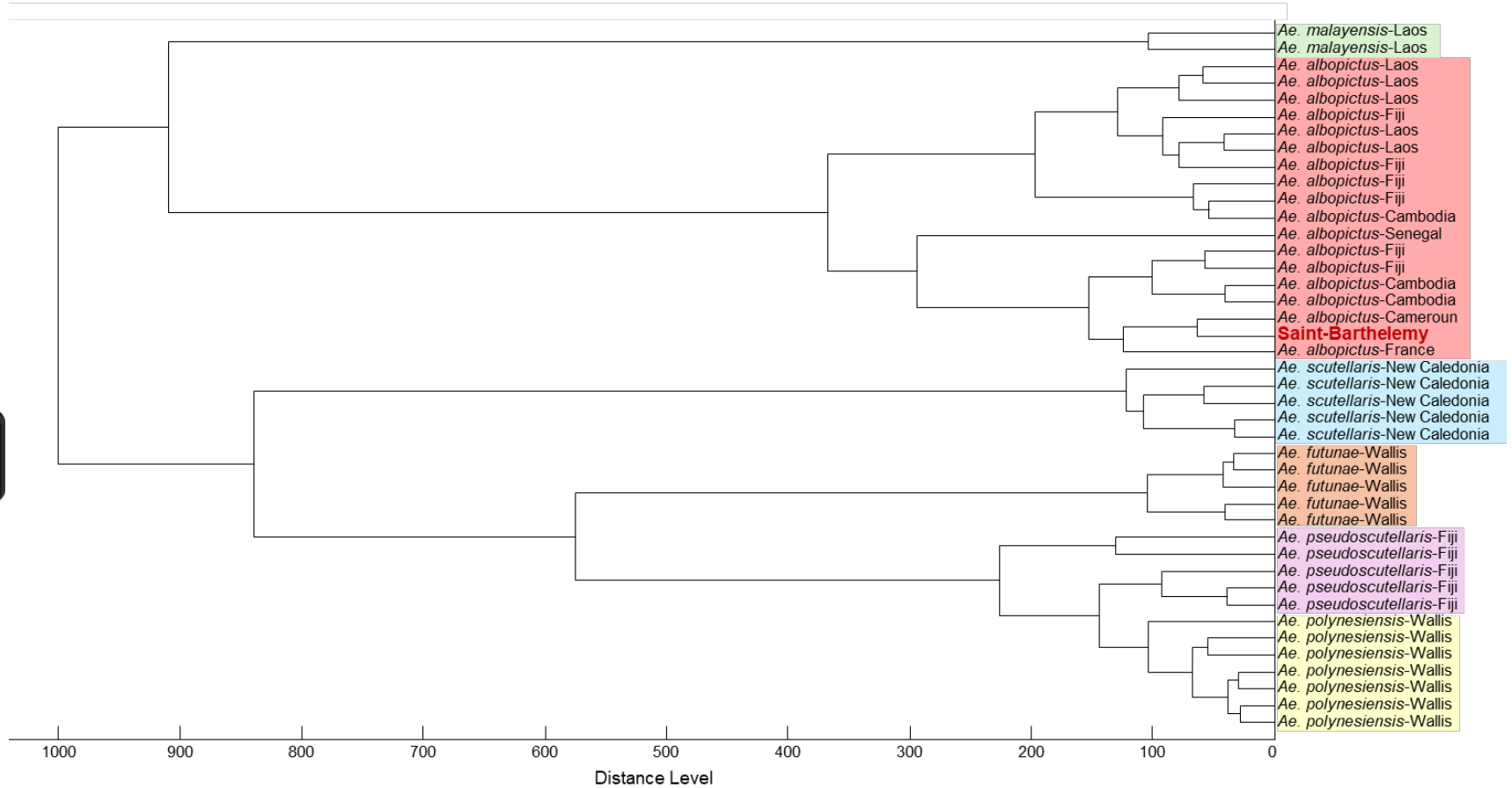
Aedes scutellaris

Aedes polynesiensis

MALDI-TOF MS approach confirmed *Ae. albopictus* ID

Legs





Ramdini *et al. in revision*

Cytochrome oxidase 1 barcoding confirmed *Ae. albopictus* ID

eurofins | Genomics

- *Aedes albopictus*
- *Aedes pseudoscutellaris*
- *Aedes polynesiensis*
- *Aedes futunae*
- *Aedes malayensis*
- *Aedes scutellaris*

Ramdini *et al. in revision*

INSTITUT PASTEUR de la Guadeloupe

Event entomological surveillance: October 14th -16th, 2024.

INSTITUT PASTEUR de la Guadeloupe

Event entomological surveillance: October 14th -16th, 2024.

***Aedes albopictus* breeding sites identified, Saint Barthélemy**

Breeding site	Coordinates	Species identified*
Floor Siphon (post office)	17°54’20”N, 62°49’28”W	*Ae. aegypti; Ae. albopictus*
Tire	17°54’16”N, 62°49’27”W	*Ae. aegypti* (6); *Ae. albopictus* (2; males)
Watering can	17°54’15”N, 62°49’32”W	*Ae. albopictus*
Flowerpot dish	17°54’21”N, 62°49’29”W	*Ae. aegypti* (10); *Ae. albopictus* (1; female)
Small container	17°54’24”N, 62°49’15”W	*Ae. albopictus*

*The number of specimens (when available) is given in parenthesis.

INSTITUT PASTEUR de la Guadeloupe

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Small container	17°54’24”N, 62°49’15”W	*Ae. albopictus*

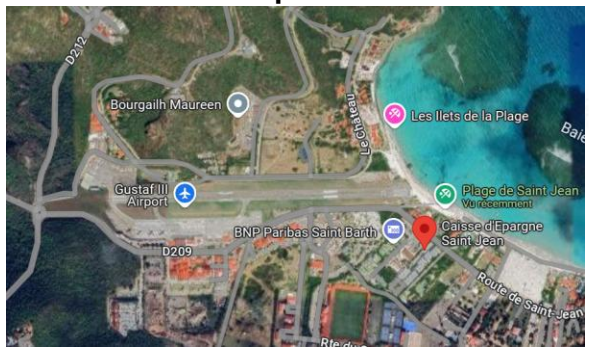
*The number of specimens (when available) is given in parenthesis.

Mixed breeding sites

INSTITUT PASTEUR de la Guadeloupe

Event entomological surveillance: Late October-November, 2024.

Near the airport!



INSTITUT PASTEUR de la Guadeloupe

Event entomological surveillance: Late October-November, 2024.

December: Insect control campaign (*Bti*, breeding sites reduction, **deltamethrin treatments** in areas surrounding positive breeding sites)

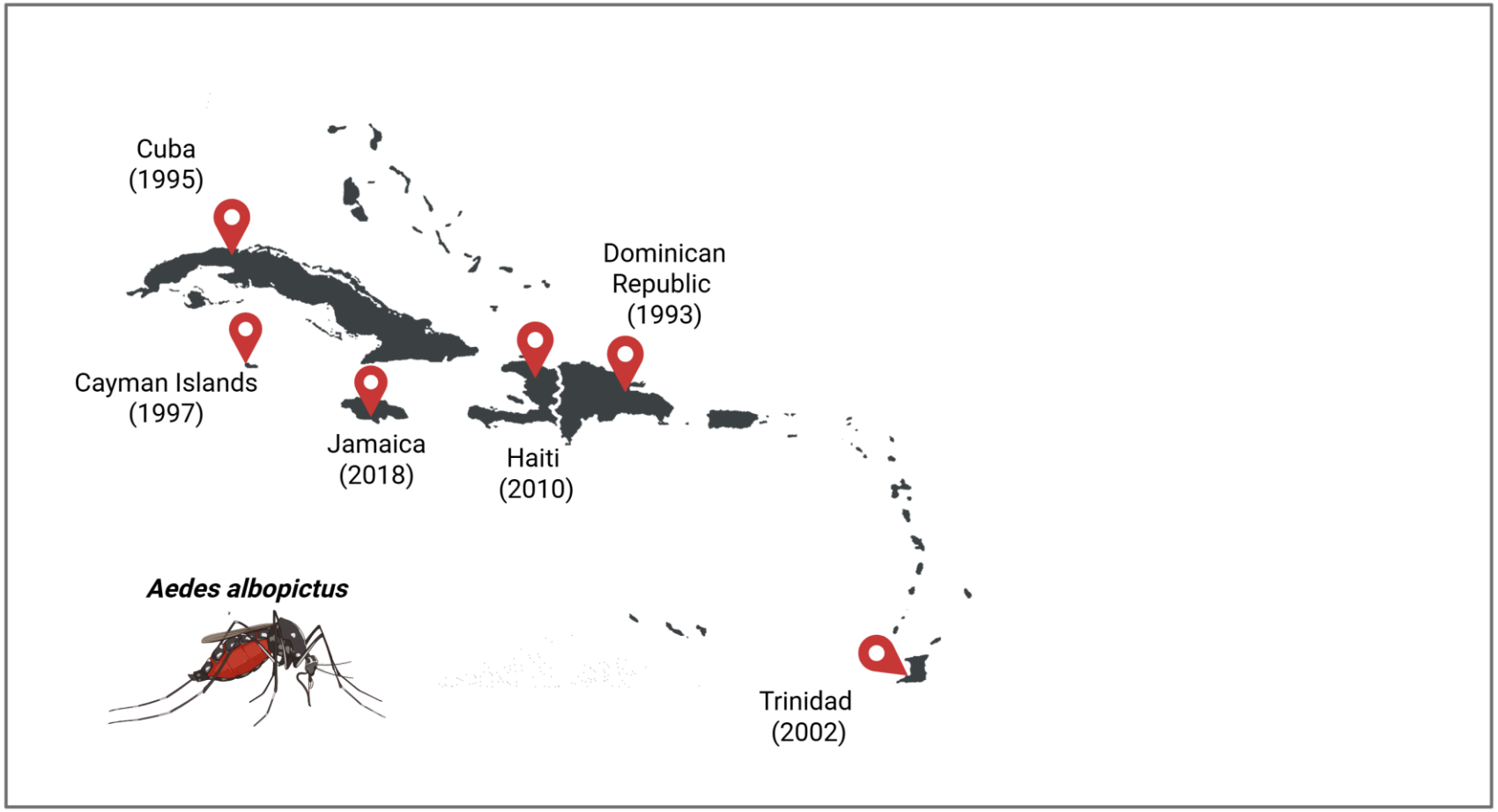
Agence de Santé Guadeloupe Saint-Martin Saint-Barthélemy

INSTITUT PASTEUR de la Guadeloupe

Entomological surveillance update: June, 2025.

Ramdini, personal communication

Ae. albopictus in the Caribbean: decades of colonisation



Peña (1993), Reiter (1998), Broche & Borja (1999), Wheeler et al (2009), Chadee D et al (2003), Marquetti Fernández et al (2012), Ali et al. (2019)

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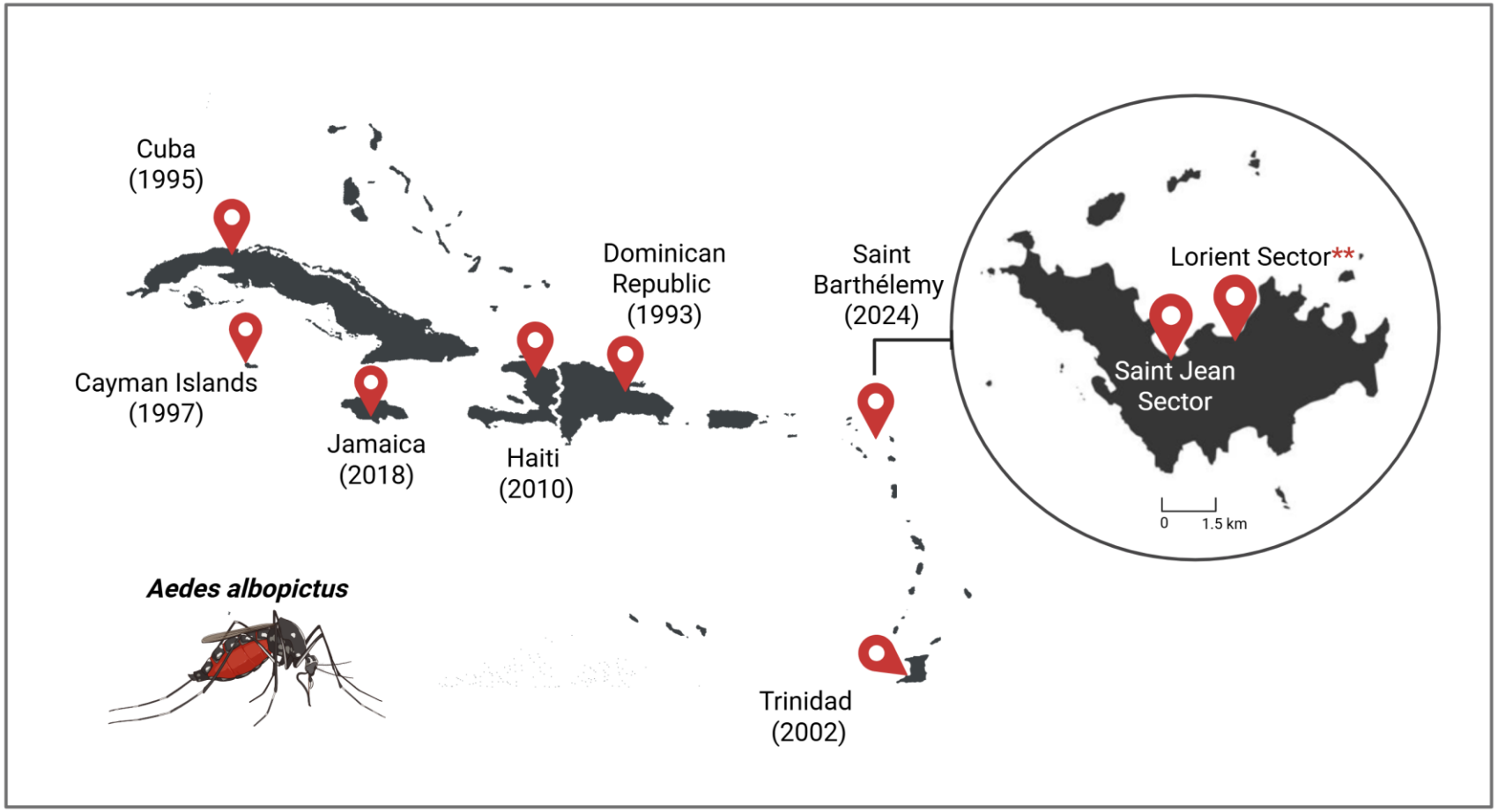
Ae. albopictus in Saint Barthélemy : the beginning of a new colonization wave?



Peña (1993), Reiter (1998), Broche & Borja (1999), Wheeler et al (2009), Chadee D et al (2003), Marquetti Fernández et al (2012), Ali et al. (2019)

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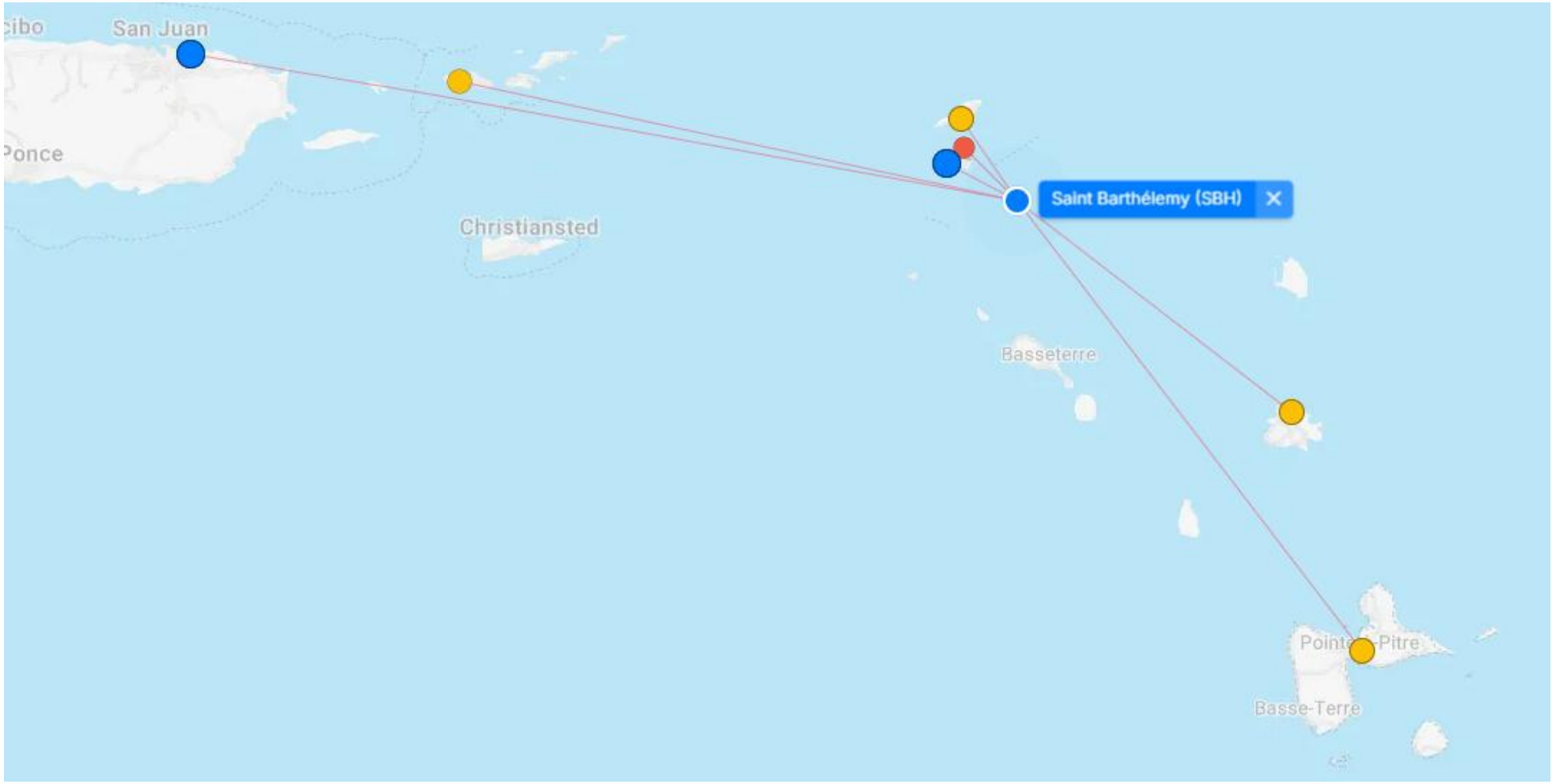
Saint Barthélemy aerial connections



https://www.flightconnections.com

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What to do in terms of vector control and surveillance?

Currently ongoing:

- Weekly, entomological surveillance is conducted in Saint Barthélemy by 2 agents (30 ovitraps, larval prospections)
- Occasional reinforcements with agents from Saint Martin (3) and/or Martinique.

Needs:

- Reinforcement of local agents (to increase the scope of vector surveillance and control actions).
- Saint Martin and Guadeloupe: Reinforce staff for entomological surveillance, particularly at ports of entry

What to do in terms of research

Currently ongoing:

- Weekly, entomological surveillance is conducted in Saint Barthélemy by 2 agents (30 ovitraps, larval prospections)
- Occasional reinforcements with agents from Saint Martin (3) and/or Martinique.

Needs:

- Reinforcement of local agents (to increase the scope of vector surveillance and control actions).
- Saint Martin and Guadeloupe: Reinforce staff for entomological surveillance, particularly at ports of entry

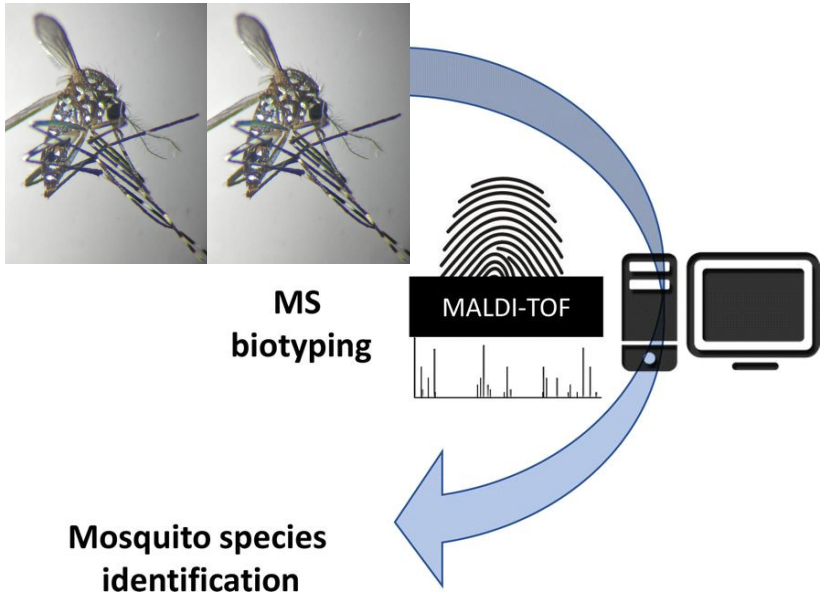
Research:

- Strengthen collaboration between ARS agents and research institutions to go deeper into surveillance data analysis and provide insights about vector ecology
- Characterize vector resistance and identify its importation origin
- Entomo-virological surveillance
- Vector competence

Acknowledgements

Thank you for your attention

Confirmation par MALDI-TOF MS



INSTITUT PASTEUR de Nouvelle-Calédonie

PASTEUR NETWORK

Mix	Detected Species	Log(Score)
	Aedes albopictusfemelle-ref-4 22-IPM	2,050
	Aedes albopictus Legs CMR	2,020
	Aedes albopictus Legs MRS	1,940
	Aedes albopictus-ref-2 20-IPM	1,890
	Aedes albopictus Legs DOU	1,860
	Aedes albopictus-Ref-CA-074-IPNC	1,830
	Aedes albopictus-ref-Fiji-021-IPNC	1,800
	Aedes albopictus-Ref-CA-073-IPNC	1,800
	Aedes albopictus-ref-Fiji-021-IPNC	1,790
	Aedes albopictusfemelle-ref-IPM1 22-IPM	1,770

MÉDITERRANÉE INFECTION

Mix	Detected Species	Log(Score)
	Aedes albopictus Thorax MRS	2,050
	Aedes albopictus Thorax CMR	1,970
	Aedes albopictus-ref-Fiji-021-IPNC	1,510
	Aedes albopictus-Ref-Fiji-021-IPNC	1,490
	Aedes albopictus Legs MRS	1,470
	Aedes albopictus-ref-Fiji-021-IPNC	1,470
	Aedes pseudoscutellaris-Ref-Fiji-314-IPNC	1,390
	Aedes albopictus-Ref-LA-030-IPNC	1,370
	Aedes pseudoscutellaris-Ref-Fiji-163-IPNC	1,310
	Aedes albopictus-Ref-Fiji-018-IPNC	1,280

Range	Description	Symbols	Color
2.300 ... 3.000	highly probable species identification	(+++)	green
2.000 ... 2.299	secure genus identification, probable species identification	(++)	green
1.700 ... 1.999	probable genus identification	(+)	yellow
0.000 ... 1.699	not reliable identification	(-)	red

FIG. 1 Meaning of Bruker Biotyper score values.

No match avec d'autres espèces du groupe *scutellaris*!

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Resistance (Ae. aegypti)

Tableau 2. Niveaux de resistance des larves des neuf populations d'*Ae. aegypti* de Guadeloupe et de Saint-Martin vis-a-vis du Temephos et du Malathion, par rapport a la souche sensible Bora-Bora.

	Temephos					
Population	**DL50 (mg/l)**	**DL50 95%CI**	**RR50**	**DL95 (mg/l)**	**DL95 95%CI**	**RR95**
Bora-Bora	0,008	0,008-0,009	1,00	0,014	0,012-0,017	1,00
LT	0,092	0,079-0,105	11,50	0,221	0,196-0,254	15,79
ABY	0,265	0,237-0,302	33,1	0,529	0,461-0,632	37,8
SF	0,123	0,111-0,136	15,4	0,233	0,211-0,262	16,6
BM	0,233	0,211-0,259	29,1	0,450	0,402-0,519	32,1
SXM (West)	0,071	0,062-0,081	8,9	0,160	0,143-0,183	11,4
SXM (East)	0,128	0,112-0,144	16,0	0,303	0,273-0,345	21,6
AB	0,132	0,115-0,152	16,5	0,557	0,440-0,763	39,8
DH	0,151	0,132-0,172	18,9	0,555	0,442-0,758	39,6
Bora-Bora	0,004	-	1,00	0,006	0,006-0,007	1,00
SBH	0,040	0,034-0,046	10,00	0,079	0,071-0,090	13,17

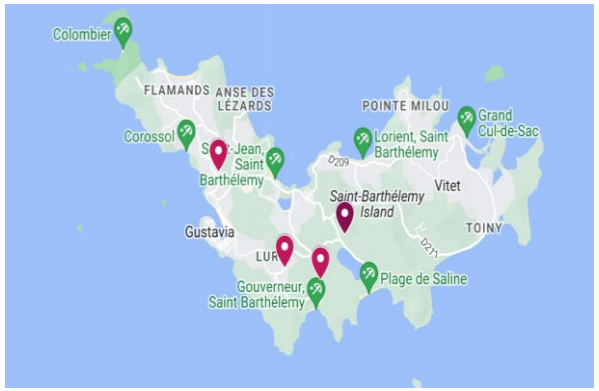

Tableau 3. Statut de resistance a la Deltamethrine des femelles adultes des huit populations d'*Ae. aegypti* de Guadeloupe, de Saint-Martin et de Saint-Barthelemy.

Concentration Deltaméthrine - Temps d'exposition	Paramètres évalués	SBH	BT/GB	DH	AB	SF	SXM	ABY	BM
0,06% - 1h	Taux de KD	1	0,86	0,93	0,94	0,98	1	0,96	0,99
	Taux de mortalité après 24h	0,83	0,83	0,83	0,64	0,79	0,88	0,79	0,9
0,08% - 1h	Taux de KD	1	1	1	0,96	1	1	0,99	1
	Taux de mortalité après 24h	0,9	1	0,94	0,93	0,81	0,98	0,85	0,99
0,05% - 2h	KRR50 (IC 95%)	9,3 (9,1-9,5)	ND	17,7 (16,7-20,5)	28,1 (24,2-34,9)	13,7 (13,0-14,4)	12,4 (12,0-12,8)	8,0 (7,8-8,3)	13,6 (13,1-14,2)
0,05% - 2h	KRR99 (ci 95%)	7,5 (7,1-8,1)	ND	10,3 (8,4-19,3)	57,5 (37,9-105,6)	23,8 (19,8-29,8)	11,1 (9,8-13,1)	10,1 (9,2-11,1)	15,3 (13,4-17,9)

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Resistance mutations: *Ae. aegypti* à Saint barth

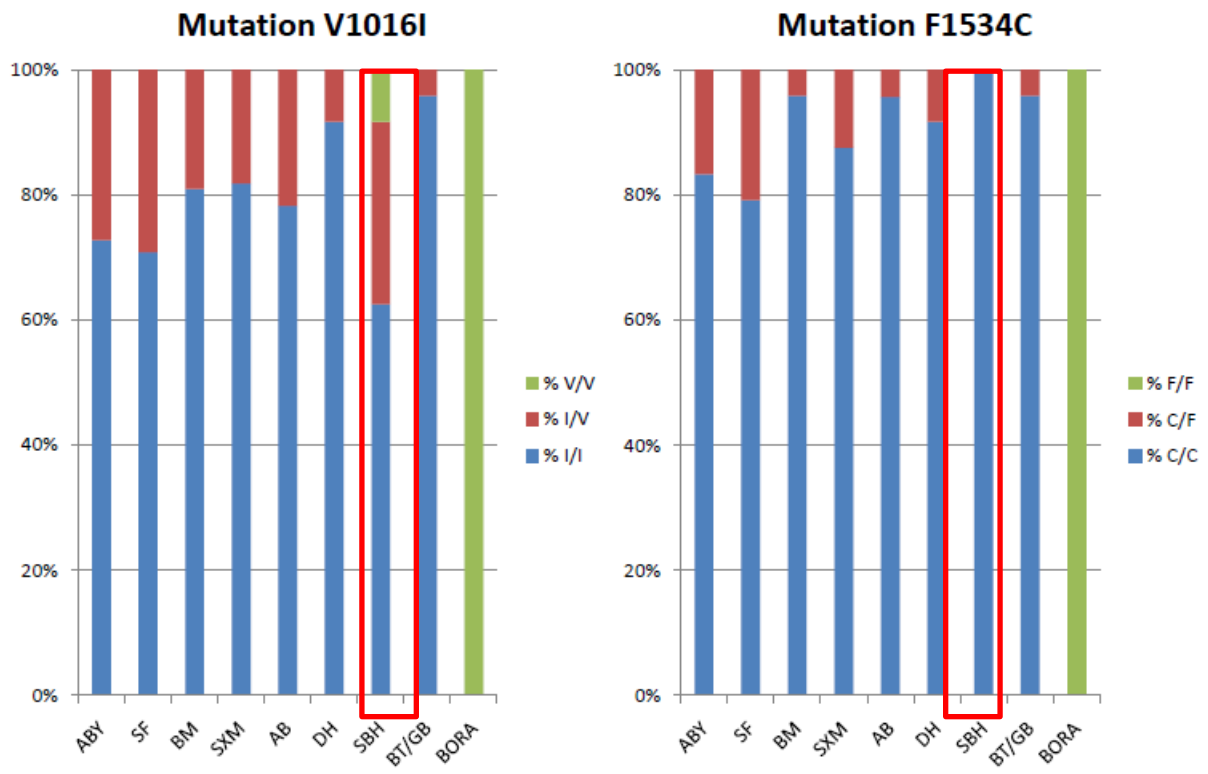

FIGURE 2. FREQUENCE GENOTYPIQUE DES MUTATIONS KDR V10161 ET F1534C CHEZ LA SOUCHE DE REFERENCE BORA BORA ET HUIT POPULATIONS D'*AE. AEGYPTI* DE GUADELOUPE, DE SAINT MARTIN ET DE SAINT-BARTHELEMY.

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Merci d’avoir suivi cette première journée !

Journées Scientifiques Annuelles d’Arbo-France

Jour 2 : Début 9H sur le 2nd lien

23-24 juin 2025, Val de Grâce - Paris