Integrated surveillance and risk assessment

NASEM Arbovirus Workshop

12 Dec2023

A/P **Ng** Lee Ching

Dengue Intervention checkpoints

Surveillance is essential

Aedes aegypti and
Aedes albopictus

Vector suppression through source reduction and Wolbachia Aedes

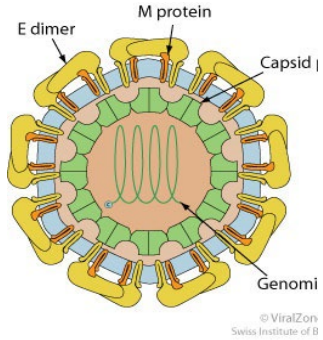
Case

Accurate Diagnostics and case notification

Cluster

Prompt intervention to mitigate transmission

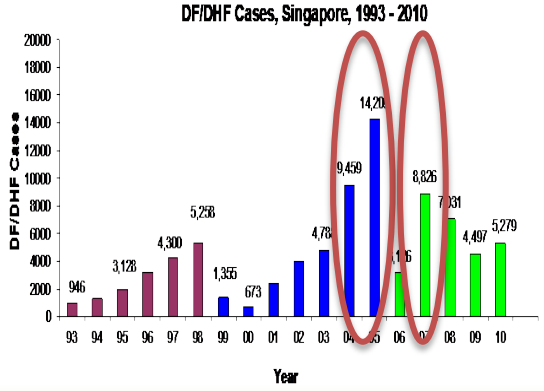
Understanding the virus – epidemic potential



Understanding immunity and epidemiology

People

Early warning for intervention and preparedness



Outbreak

Understanding environmental risk factors

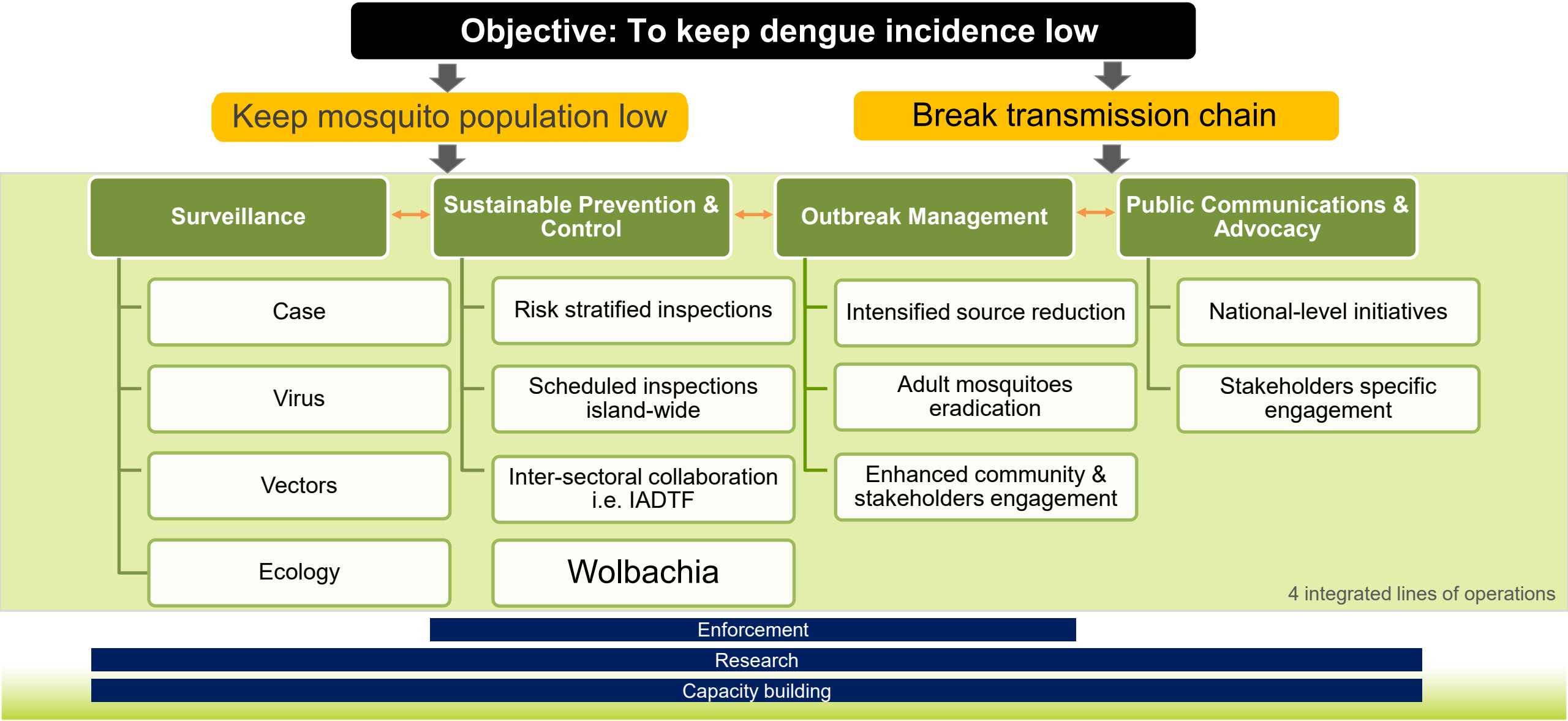
NEA's dengue control framework

An evidence-based integrated vector management approach

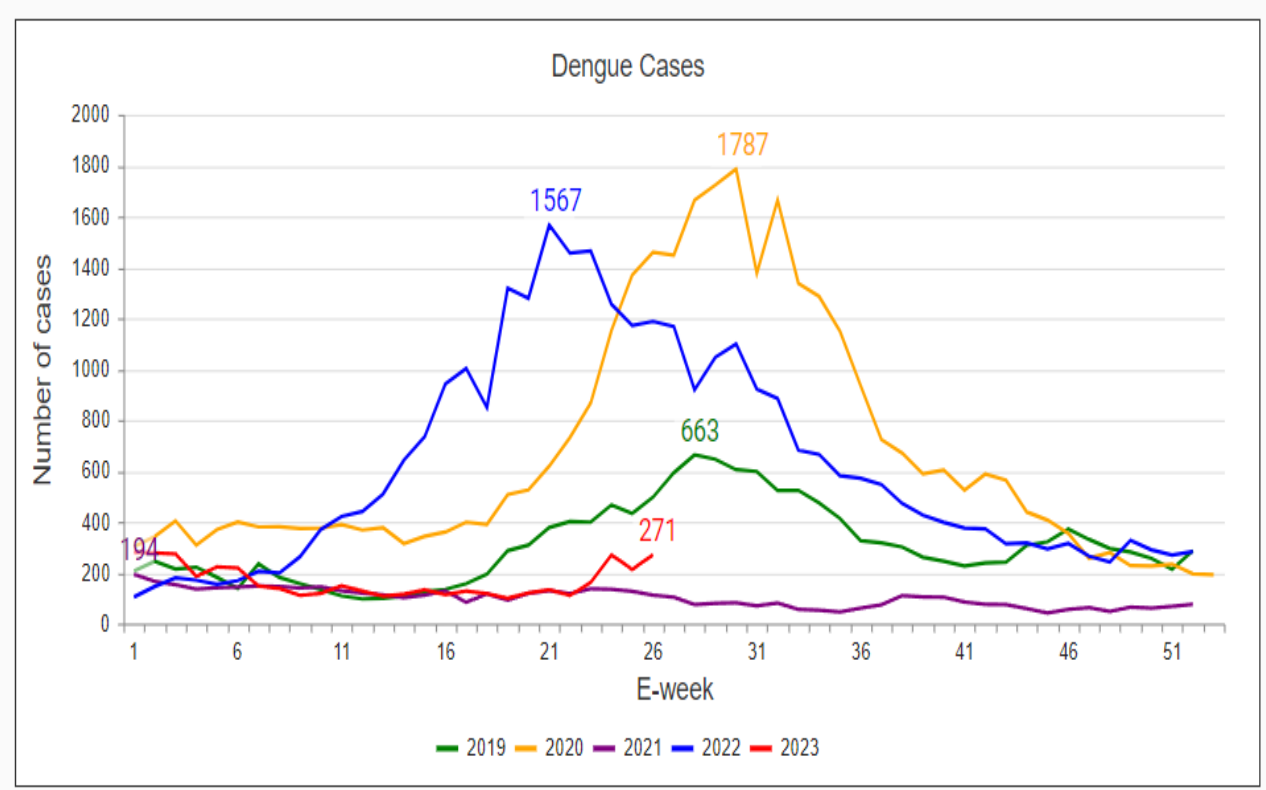
Sim et al 2020. A greener vision for vector control… PLoS Negl Trop Dis 14(8):e0008428

Aik J, et al 2019 The effectiveness of inspections on reported mosquito larval habitats in households… PloS NTD. 13(6):e0007492

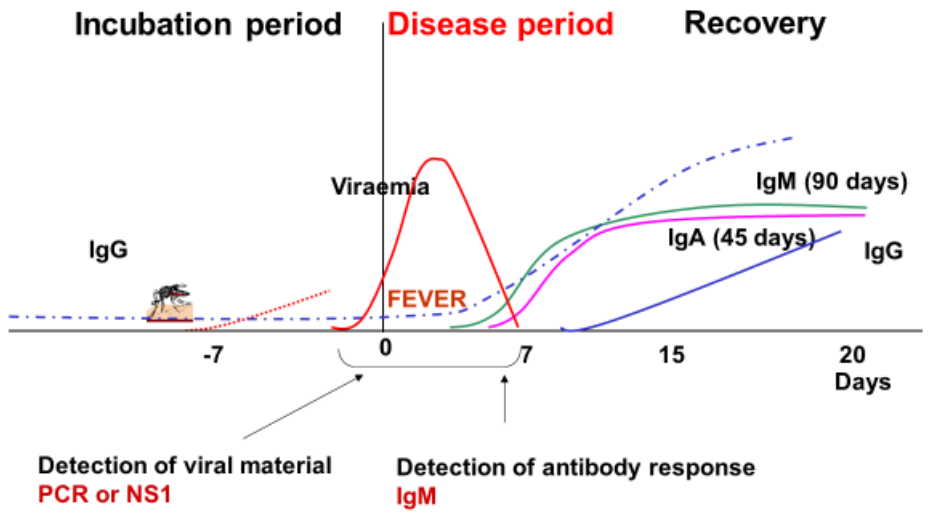
Ho et al. 2023. Singapore's 5 decades of dengue prevention and control—Implications for global dengue control. PLoS Negl Trop Dis 17(6): e001140



Case surveillance – mandatory reporting by clinicians and laboratories

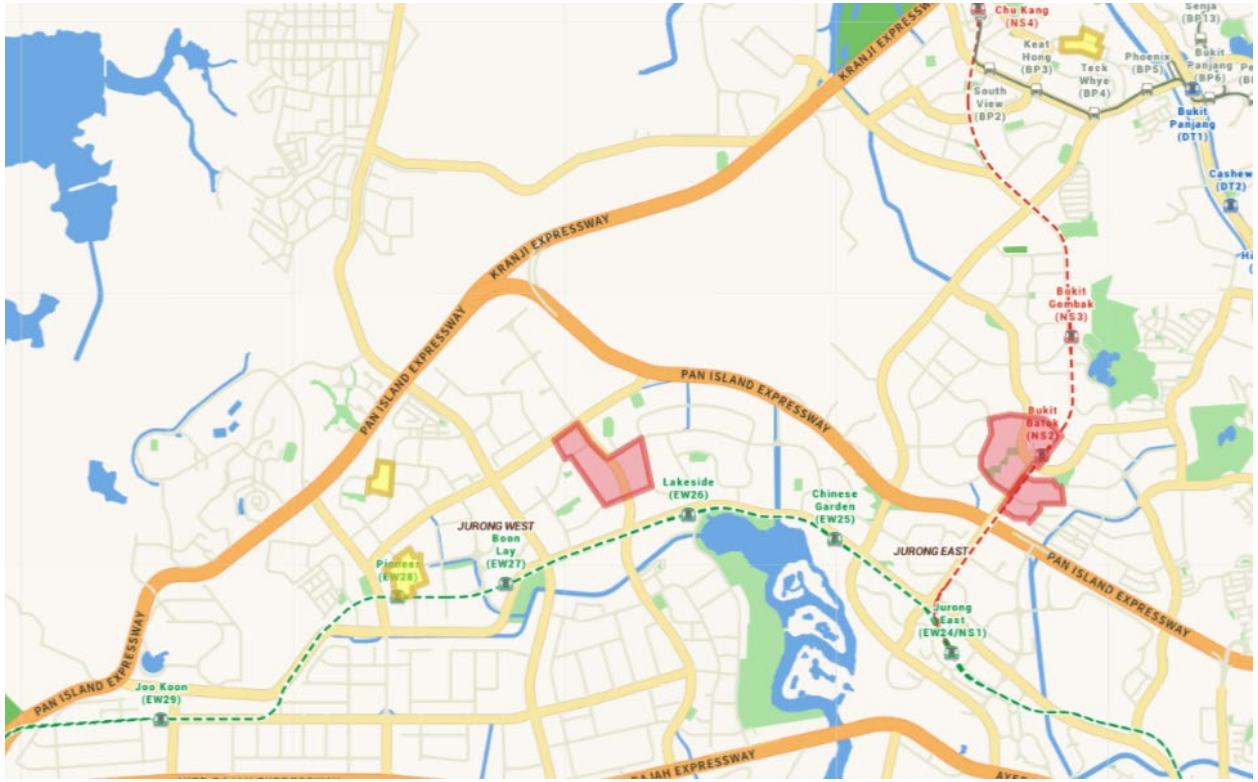


Laboratory Diagnostics



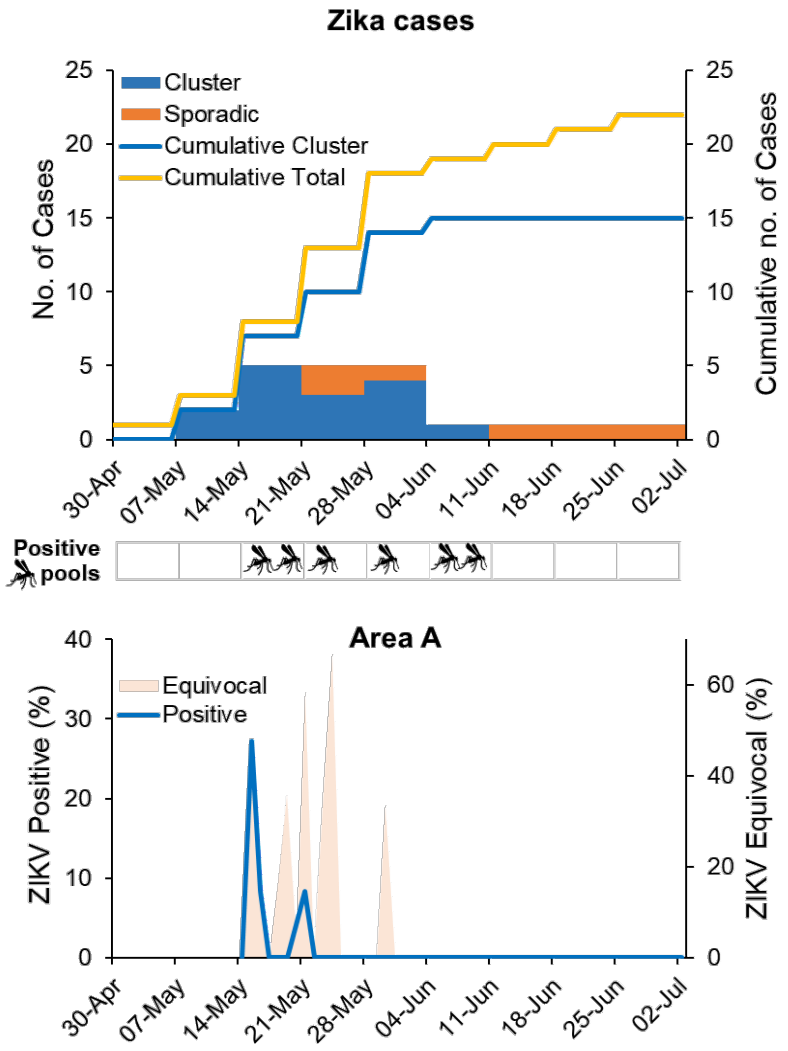
NS1 positive - subject to serotype determination and sequencing
Dengue negative samples – subject to Flaviviruses abd Chikungunya PCR – caught Zika and chik cases

Alerting the community on dengue, chikungunya or zika transmission

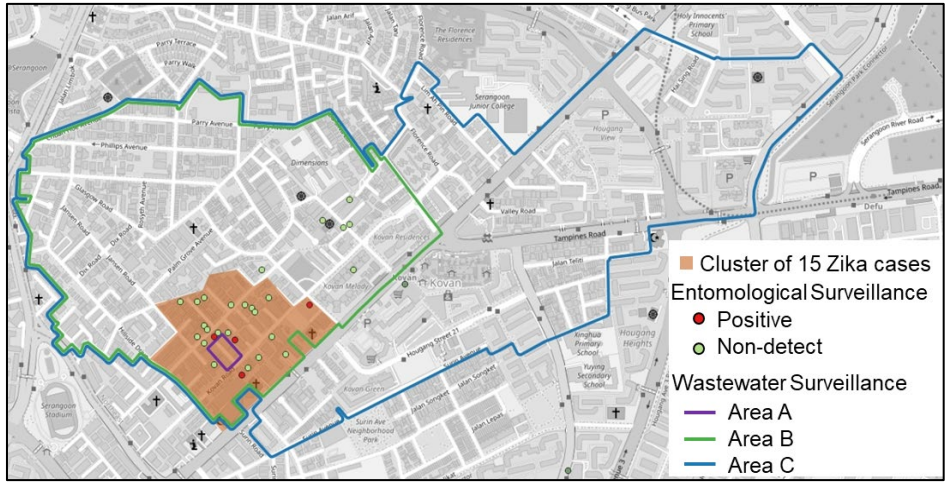


https://www.nea.gov.sg/dengue-zika/dengue/dengue-clusters

Wastewater surveillance to complement clinical surveillance



ZIKV signals in wastewater corroborates rise in cases at cluster and virus in *Aedes* mosquitoes



Higher sensitivity needed for Dengue

Aircraft wastewater testing for Zika

Wong et al., SSRN

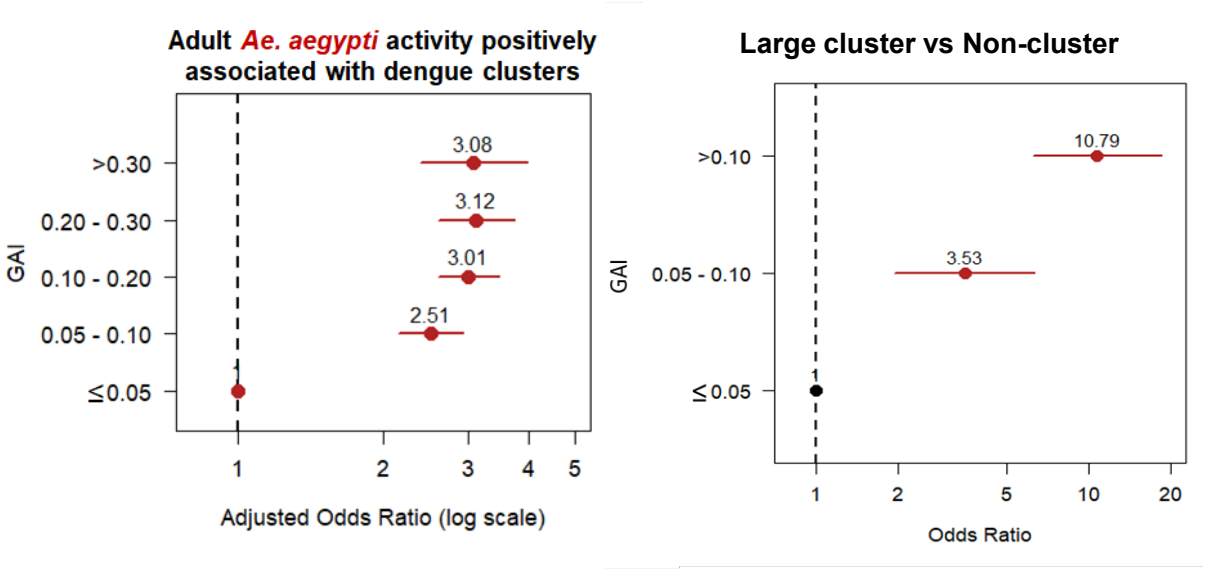
Aedes Surveillance – shift to adult monitoring

Deployment of 70,000 traps island-wide

Gravitrap *Ae. aegypti* Index (GAI) = no. of female *Aedes aegypti* trapped / no. of traps

- Indication of risk of transmission
- Know where the mosquitoes are

- 3-D spatial distribution
- Testing of virus
- Implication of vector



Method published in Ong J, Aik J, Ng LC (2021) PLoS Negl Trop Dis 15(6): e0009475

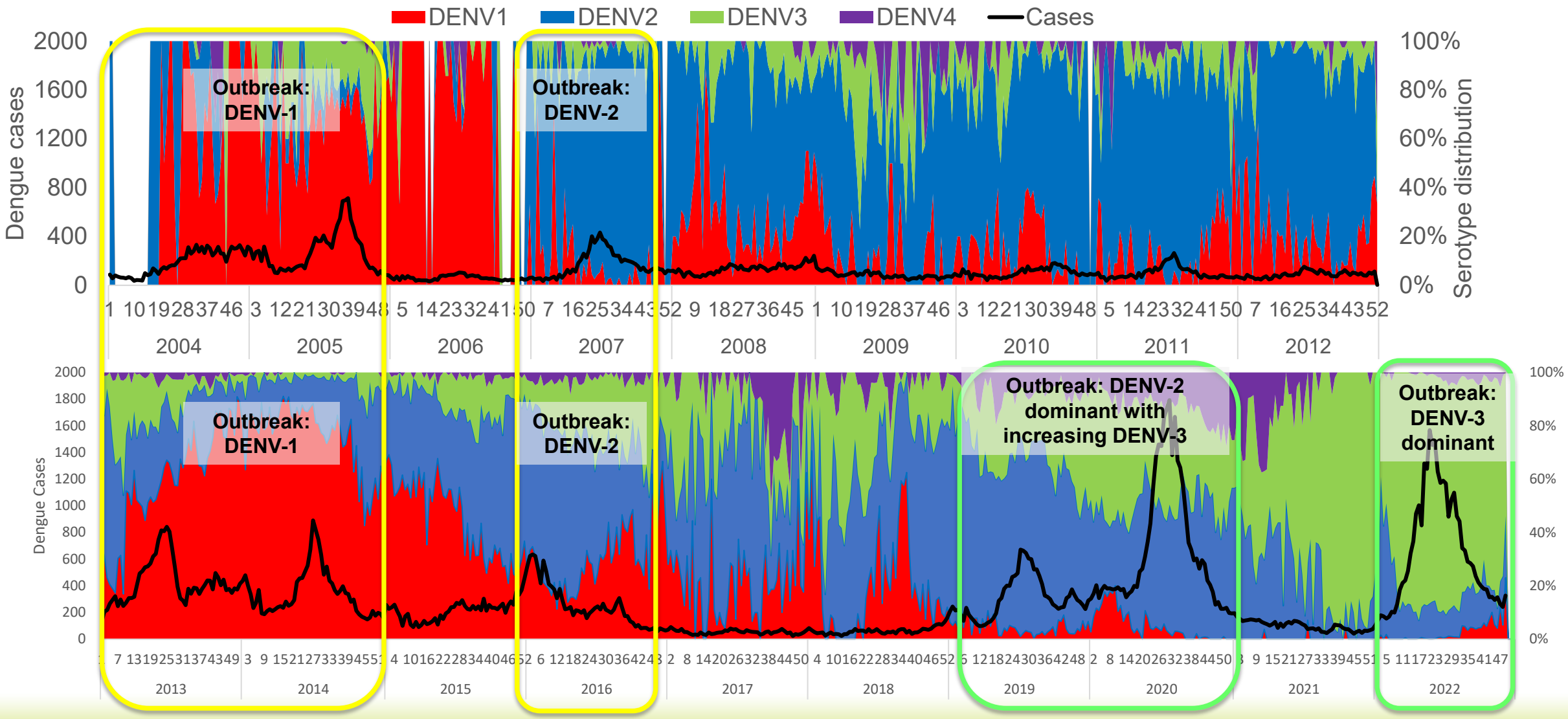
Alerting public on high *Aedes aegypti* population

Data available at MyENV app and www.nea.gov.sg/dengue-zika/Aedes

Virus Serotype and genotype monitored since 2007

Switch in predominant serotype as a signal of potential outbreak

Rajarethinam J, et al 2018 Am J Trop Med Hyg.



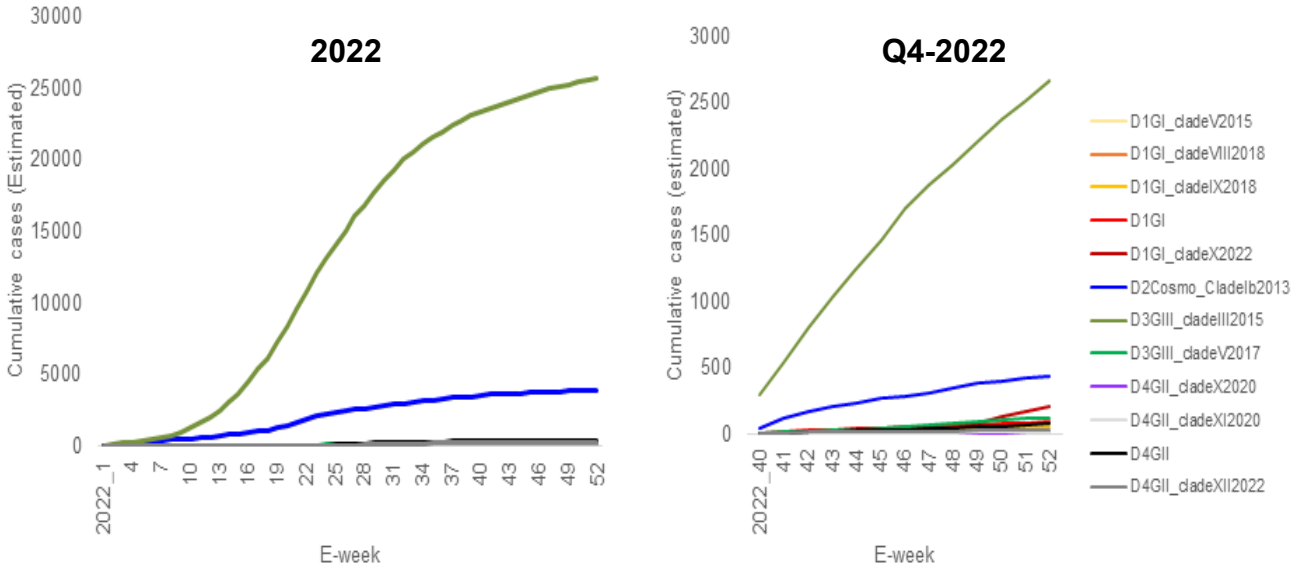
Dengue virus monitoring for dengue control and management

Pre-empted 2022 outbreak

Accumulation rates of DENV-3 Genotype III clade III (olive green) since late 2021

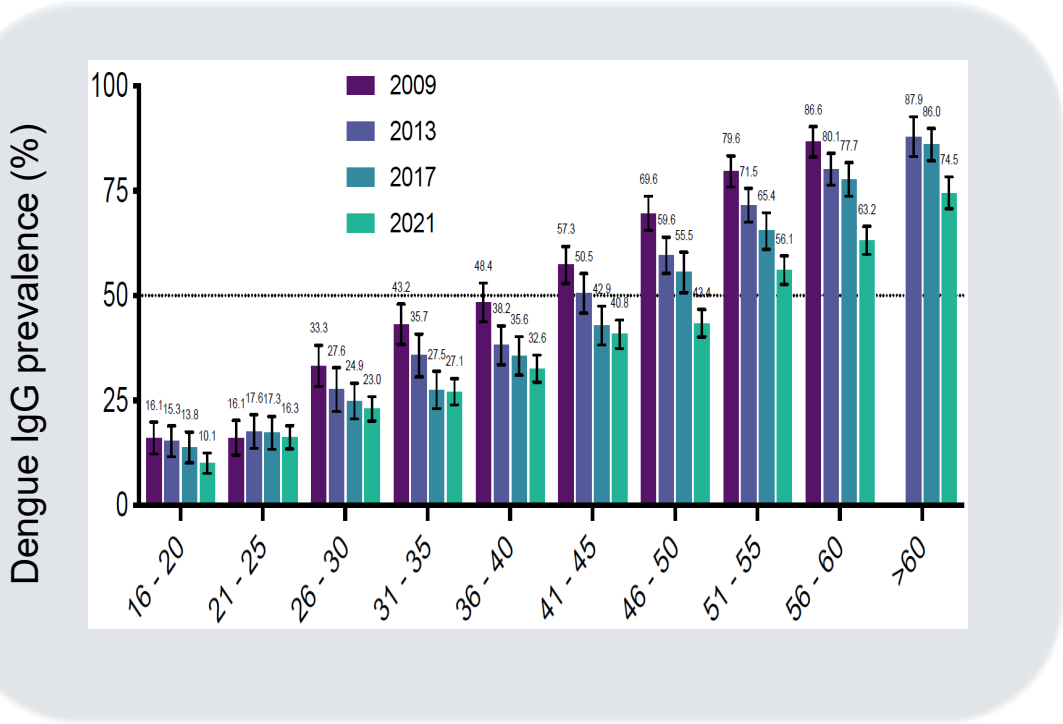
Epidemic potential of dominant virus

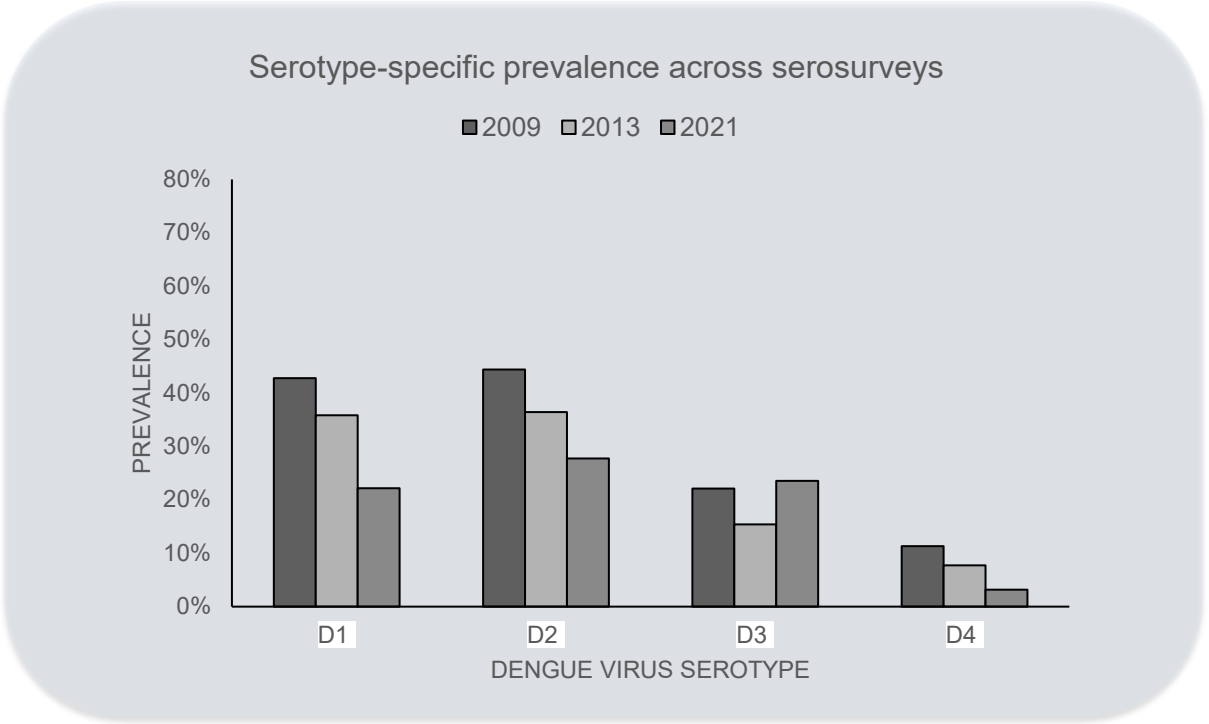
Accumulation rate of circulating genotypes: 2022



Mosquito infection % mosquitoes with dengue virus in their saliva			
	Days from feeding on blood with virus		
	6	9	13
DENV-2 (cosmo clade 1b) (6log$TCID_{50}$/mL)	60%	70%	80%
DENV-3 (4.5log$TCID_{50}$/mL)	60%	60%	90%

Understanding immunological vulnerability





- Holistic assessment for annual Dengue Outlook used for planning of vector control operations, hospitals and community mobilisation

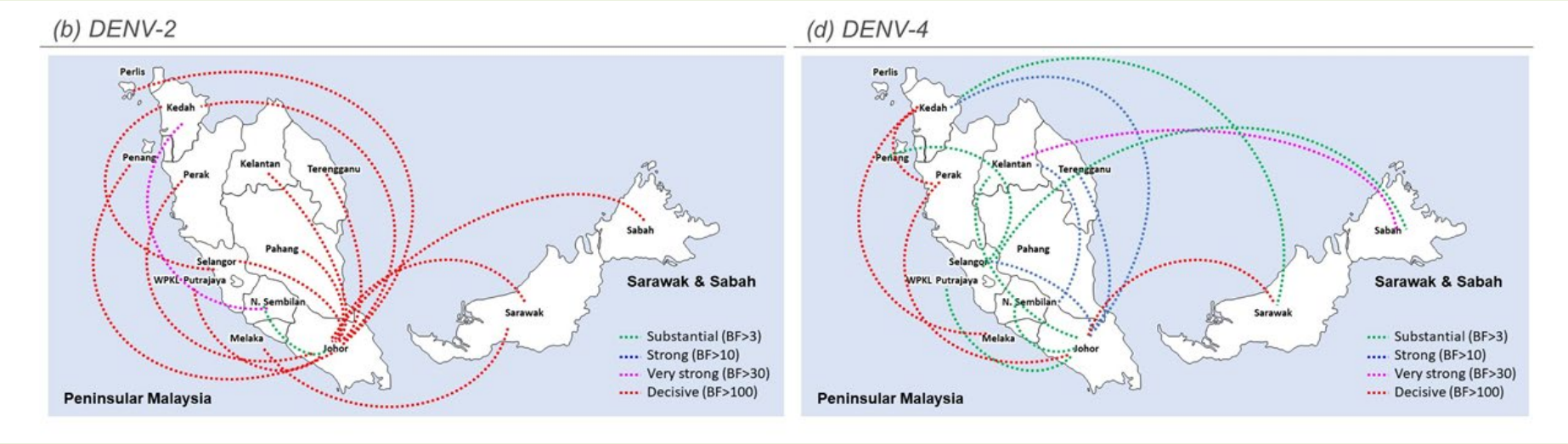
Low SL, et al.. 2015. Dengue seroprevalence of healthy adults in Singapore…. American Journal of Tropical Medicine & Hygiene 93:40–45.

Genetic Diversity and Dispersal of DENGUE Virus among Three Main Island Groups of the Philippines during 2015–2017

Ava Kristy Sy [1], Carmen Koo [2], Kristine J R Privaldos [1], Mary Ann T Quinones [1], Mary A U Igoy [1], Sharon Y A M Villanueva [3], Martin L Hibberd [4 5 6 7], Lee Ching Ng [2 8], Hapuarachchige C Hapuarachchi [2]

Luzon - a major source of DENV emergence
Calabarzon important hubs of virus dispersal

Molecular epidemiology of dengue in Malaysia, 2015-20211



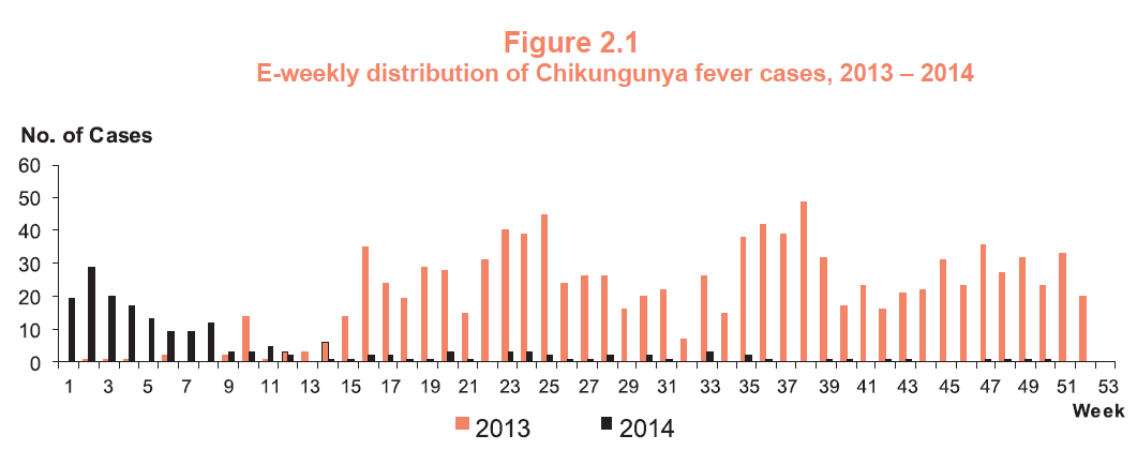
Chikungunya virus A226V led to revision of vector control tactic

- targeting Aedes albopictus as well as Ae. aegypti

2013 Outbreak

Entomologic and Virologic Investigation of Chikungunya, Singapore

Lee-Ching Ng, Li-Kiang Tan, Cheong-Huat Tan, Sharon S.Y. Tan, Hapuarachchige C. Hapuarachchi, Kwoon-Yong Pok, Yee-Ling Lai, Sai-Gek Lam-Phua, Göran Bucht, Raymond T.P. Lin, Yee-Sin Leo, Boon-Hian Tan, Hwi-Kwang Han, Peng-Lim S Ooi, Lyn James, and Seow-Poh Khoo



Transient transmission of Chikungunya virus in Singapore exemplifies successful mitigation of severe epidemics in a vulnerable population

Hapuarachchige Chanditha Hapuarachchi [1 £], Wing-Yan Wong [1 £], Carmen Koo [1], Wei-Ping Tien [1], Gladys Yeo [1], Jayanthi Rajarethinam [1], Eugene Tan [1], Suzanna Chiang [1], Chee-Seng Chong [1], Cheong-Huat Tan [1], Li-Kiang Tan [1 ¶], Lee-Ching Ng [1 2]

Regular trapping and testing of Culex for other zoonotic Flaviviruses

Article

Isolation and Genetic Characterization of Japanese Encephalitis Virus Two Decades after Its Elimination in Singapore

Ming Jie Lim [1,*], Zhi Yang Loh [1], Hui Ling Yeo [1], Surya Pavan Yenamandra [1], Marcella Kong [1], Hao Yang Pang [1], Meng Han Lee [1], Mahathir Humaidi [1], Cliff Chua [1], Jane Griffiths [1], Lee Ching Ng [1,2], Hapuarachchige Chanditha Hapuarachchi [1] and Diyar Mailepessov [1]

Table 1. Field-caught *Culex* mosquitoes in the present study. See Table S2 for more details on the distribution of mosquitoes in the present study.

Classification	CDC Light Traps				Night Catcher Traps			
	No. of Mosquitoes Collected	No. of Mosquito Pools	No. of JEV-Positive Pools	Detection Percentage [1] (%)	No. of Mosquitoes Collected	No. of Mosquito Pools	No. of JEV-Positive Pools	Detection Percentage [1] (%)
Culex spp. [2]	13,845	213	5	2.35	-	-	-	-
Cx. bitaeniorhynchus	33	17	0	0	32	4	0	0
Cx. gelidus	114	67	0	0	204	10	0	0
Cx. quinquefasciatus	2882	93	0	0	1	1	0	0
Cx. sitiens	1497	535	0	0	249	12	0	0
Cx. tritaeniorhynchus	14,258	926	2	0.22	10,223	291	3	1.03
Culex spp. *vishnui* subgroup [3]	9646	1021	0	0	1324	71	0	0

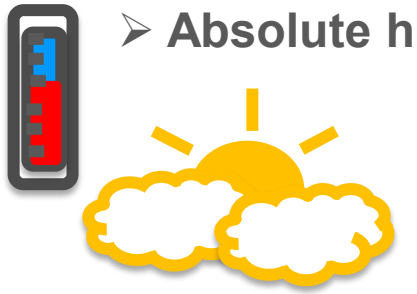
[1] JEV-positive pools/total pools. [2] From September to October 2019 only. [3] Excluding *Cx. tritaeniorhynchus*.

Genetic sequences suggests multiple introduction and enzootic cycle

Using Big Data Analytics

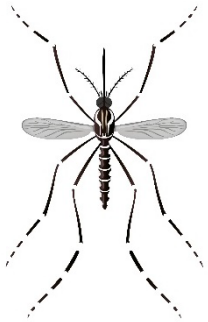
Climate data

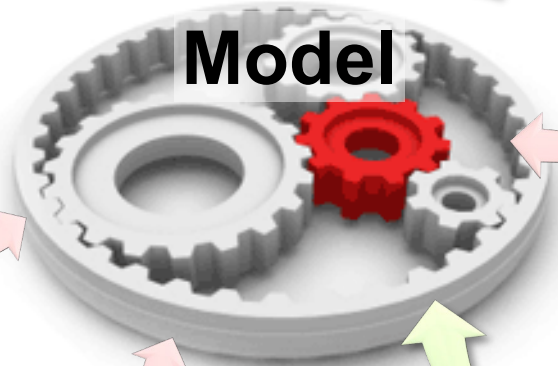
- Temperature
- Absolute humidity



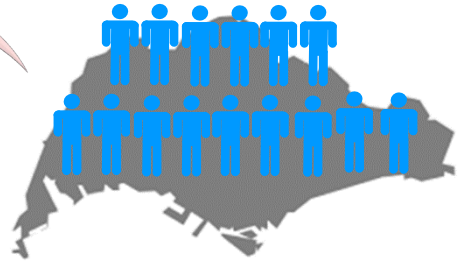
Vector data

- Breeding index
- Gravitrap index





Population demography



Satellite data

- Vegetation index

Infrastructure data

- Age of buildings
- No. of units

Case and virus data

- Weekly dengue cases

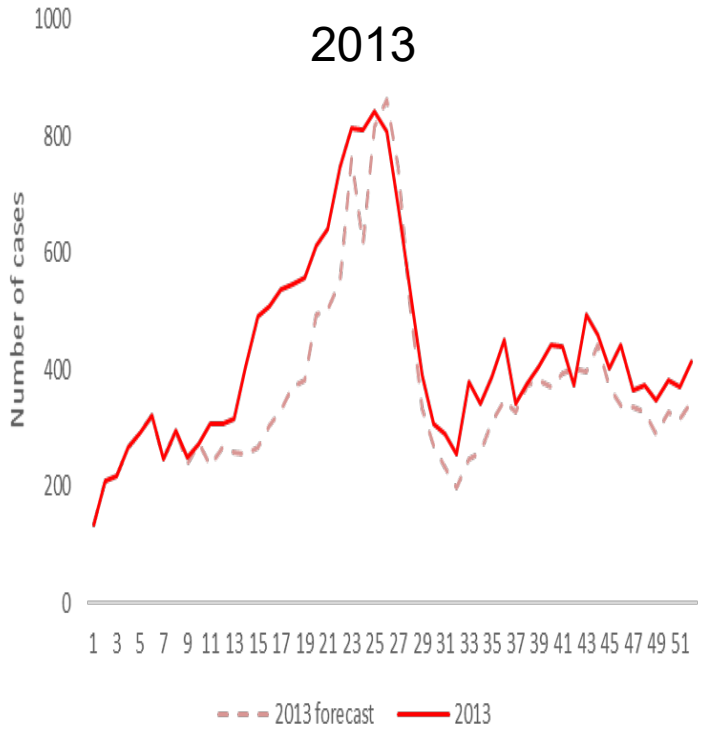
Temporal model for preparedness

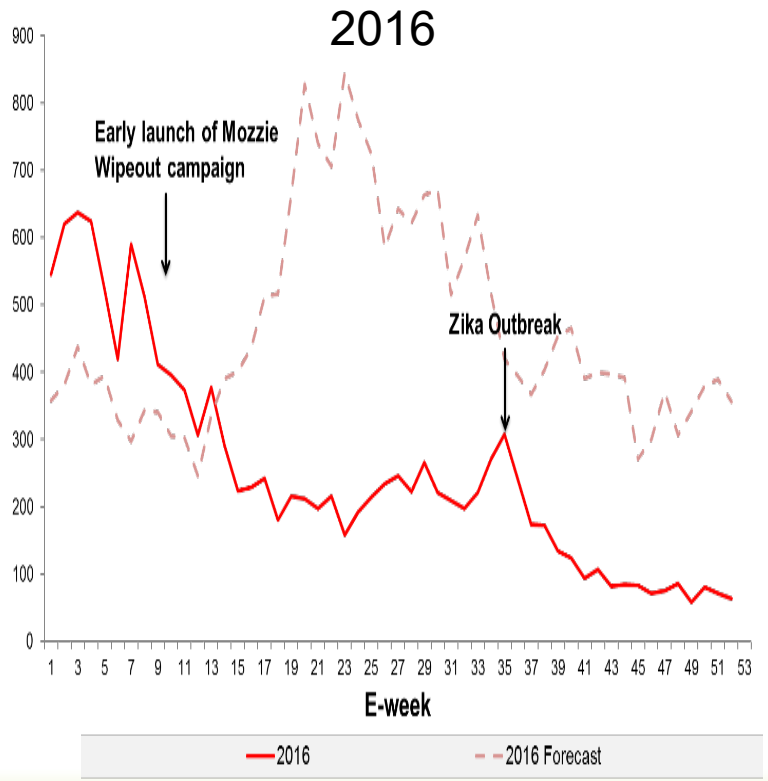
Environ Health Perspect; DOI:10.1289/ehp.1509981

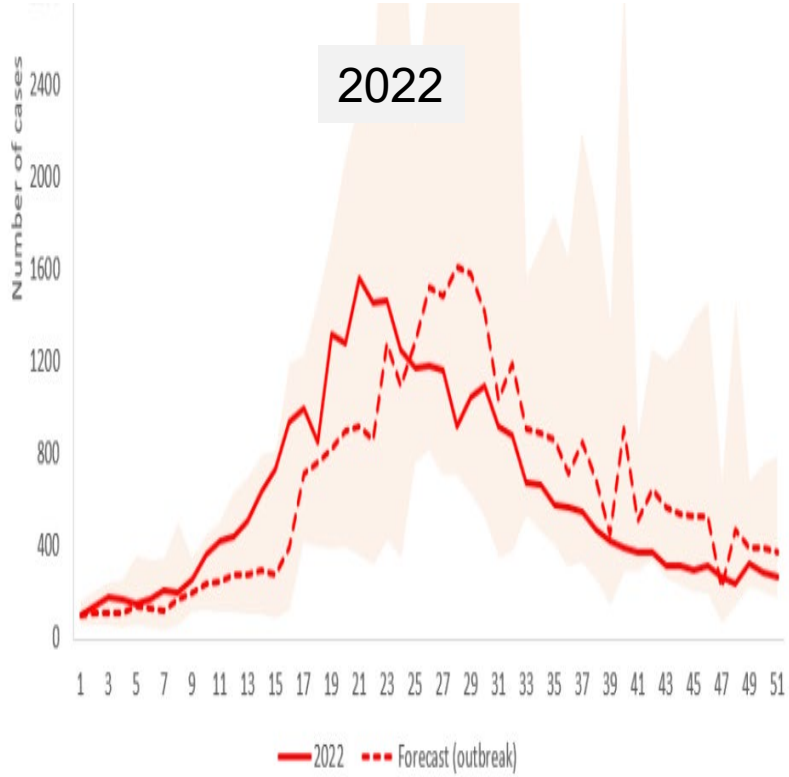
Three-Month Real-Time Dengue Forecast Models: An Early Warning System for Outbreak Alerts and Policy Decision Support in Singapore

Yuan Shi[1], Xu Liu[1], Suet-Yheng Kok[1], Jayanthi Rajarethinam[1], Shaohong Liang[1], Grace Yap[1], Chee-Seng Chong[1], Kim-Sung Lee[1], Sharon S.Y. Tan[2], Christopher Kuan Yew Chin[1], Andrew Lo[3], Waiming Kong[4], Lee Ching Ng[1,5], and Alex R. Cook[6,7]

Based on Lasso





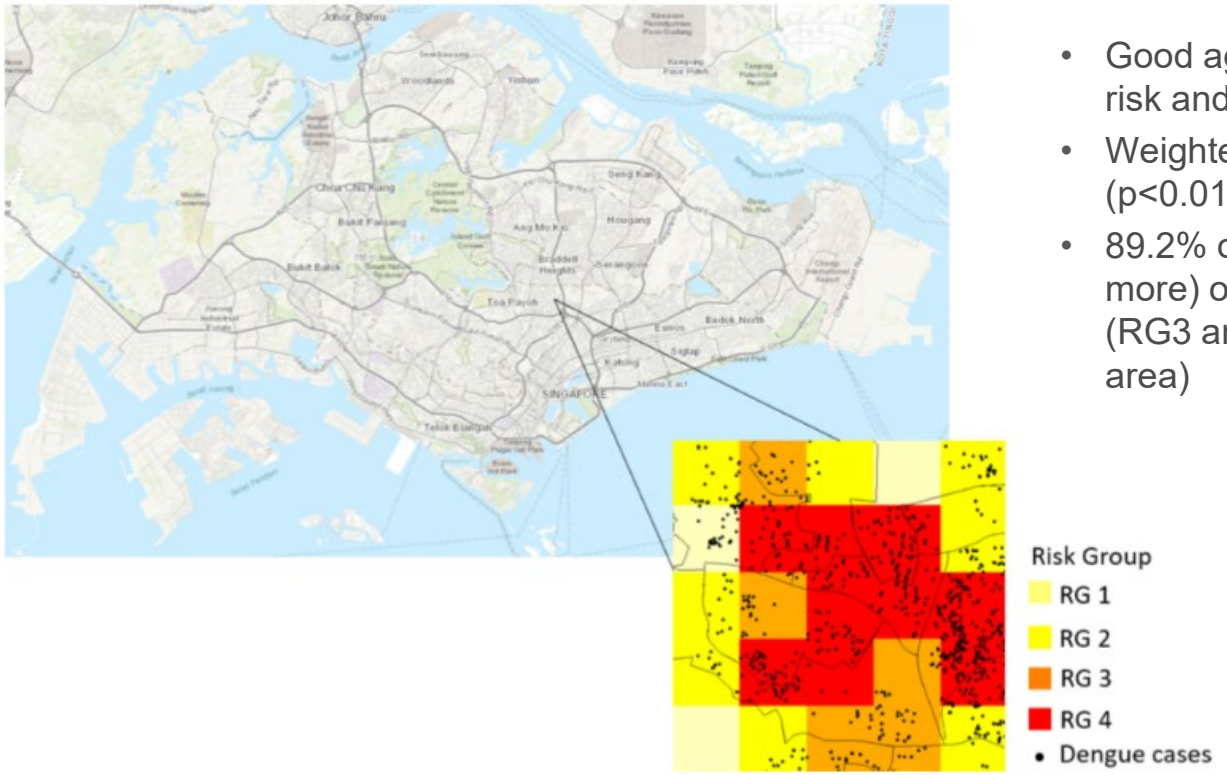


Spatial risk map for strategic resource allocation

RESEARCH ARTICLE

Mapping dengue risk in Singapore using Random Forest

Janet Ong[1], Xu Liu[1], Jayanthi Rajarethinam[1], Suet Yheng Kok[1], Shaohong Liang[1], Choon Siang Tang[2], Alex R. Cook[3], Lee Ching Ng[1,4]*, Grace Yap[1]



- Good agreement between predicted risk and actual case count
- Weighted Kappa Coefficient of 0.821 ($p<0.01$)
- 89.2% of large clusters (10 cases or more) occurred in high risk areas (RG3 and 4, 50% of the residential area)

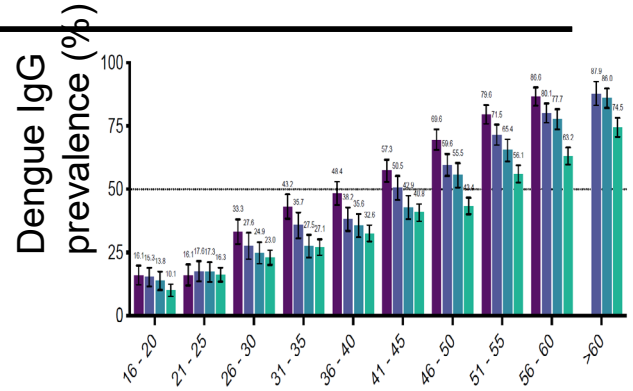
Ong et al. 2018, *PLOS NTD*

Evaluation of Vector Control programme and estimating disease burden

Practice of Epidemiology

Force of Infection and True Infection Rate of Dengue in Singapore: Implications for Dengue Control and Management

Li Kiang Tan, Swee Ling Low, Haoyang Sun, Yuan Shi, Lilac Liu, Sally Lam, Hwee Huang Tan, Li Wei Ang, Wing Yan Wong, Rachel Chua, Diana Teo, Lee Ching Ng*, and Alex R. Cook

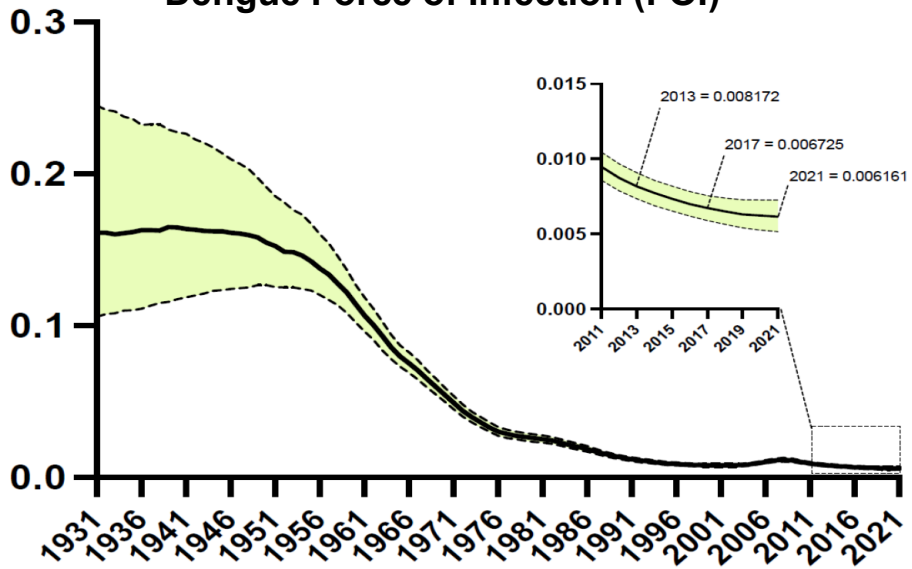


RESEARCH ARTICLE

Economic impact of dengue in Singapore from 2010 to 2020 and the cost-effectiveness of Wolbachia interventions

Stacy Soh[1], Soon Hoe Ho[1], Annabel Seah[1], Janet Ong[1], Borame Sue Dickens[2], Ken Wei Tan[2], Joel Ruihan Koo[2], Alex R. Cook[2], Kelvin Bryan Tan[3], Shuzhen Sim[1], Lee Ching Ng[1,4], Jue Tao Lim[1,2]*

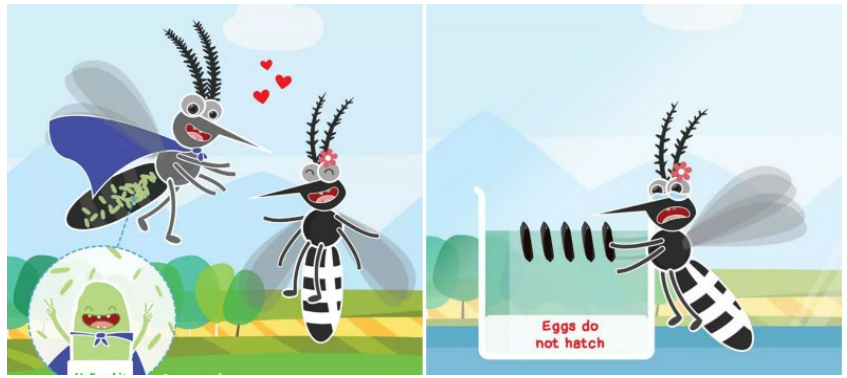
Dengue Force of Infection (FOI)

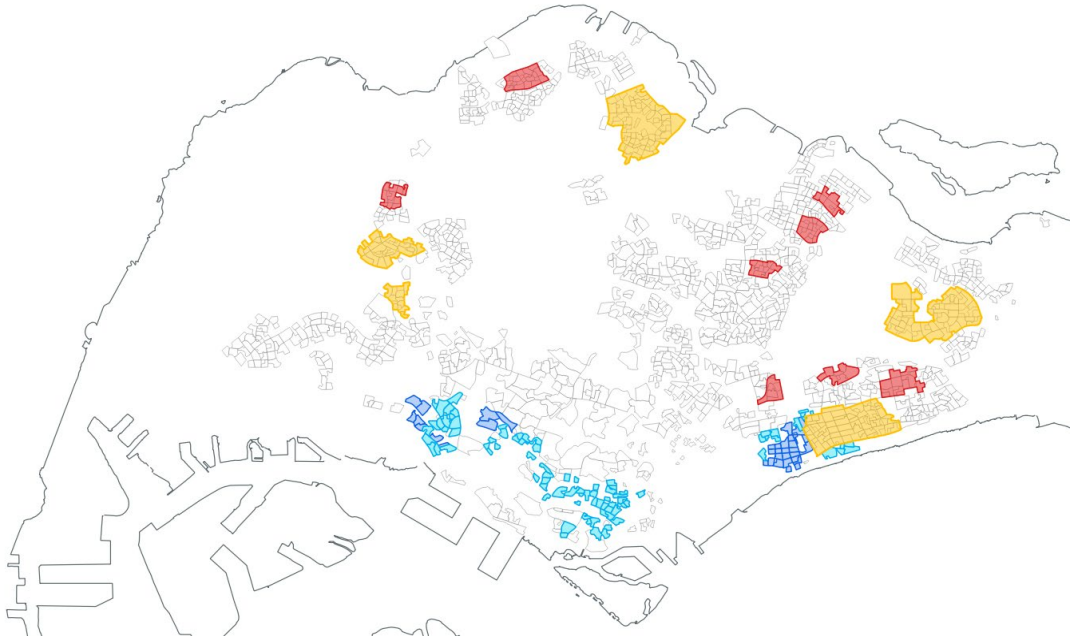


FOI: probability of a susceptible individual acquiring a primary infection per year

Evaluation of vector control tools

PROJECT WOLBACHIA SINGAPORE



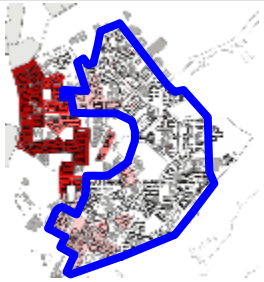
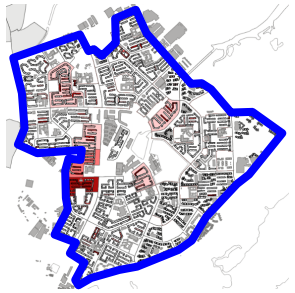
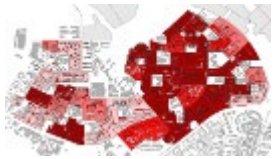
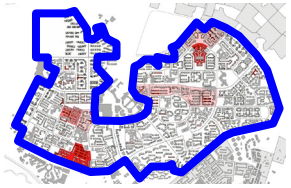


480,000 households, 35% of all households in Singapore, by Q1 2024

Gravitrap data for estimating entomological impact

"Eraser" effect on *Ae. aegypti* population, more than 90% reduction in Ae. Aegypti population

PROJECT WOLBACHIA SINGAPORE

Sites	Jun 2018	Jun 2019	Jun 2020	Jun 2021	Jun 2022	May 2023
Yishun		 84 blocks (7,952 homes)	 293 blocks (29,656 homes)	 417 blocks (40,314 homes)	 668 blocks (67,051 homes)	
Tampines		 60 blocks (5,560 homes)	 260 blocks (26,298 homes)	 443 blocks (40,399 homes)	 731 blocks (68,012 homes)	

GAI[1]	<0.05	0.05-0.1	>0.1

Release area
(weekly releases since Jul 2018 in Yishun and Sep 2018 in Tampines)

1: Gravitrap *Ae. aegypti* index (GAI, average number of female *Aedes aegypti* caught per functional gravitrap)

Evaluation of vector control tool – epidemiological endpoints

Estimating intervention efficacy with at least 6 month of releases, based on national surveillance data

	Bukit Batok	Choa Chu Kang	Tampines	Yishun
Coverage of town (%)	73	78	62	73
Total cases IE (%)	**66**	**53**	**66**	**71**
Clustered cases IE (%)	53	66	78	83
Sporadic cases IE (%)	-2	-53	-17	-19

Estimating risk reduction (%) to individuals living in treatment area based on nationwide diagnostic test results (negative/positive)

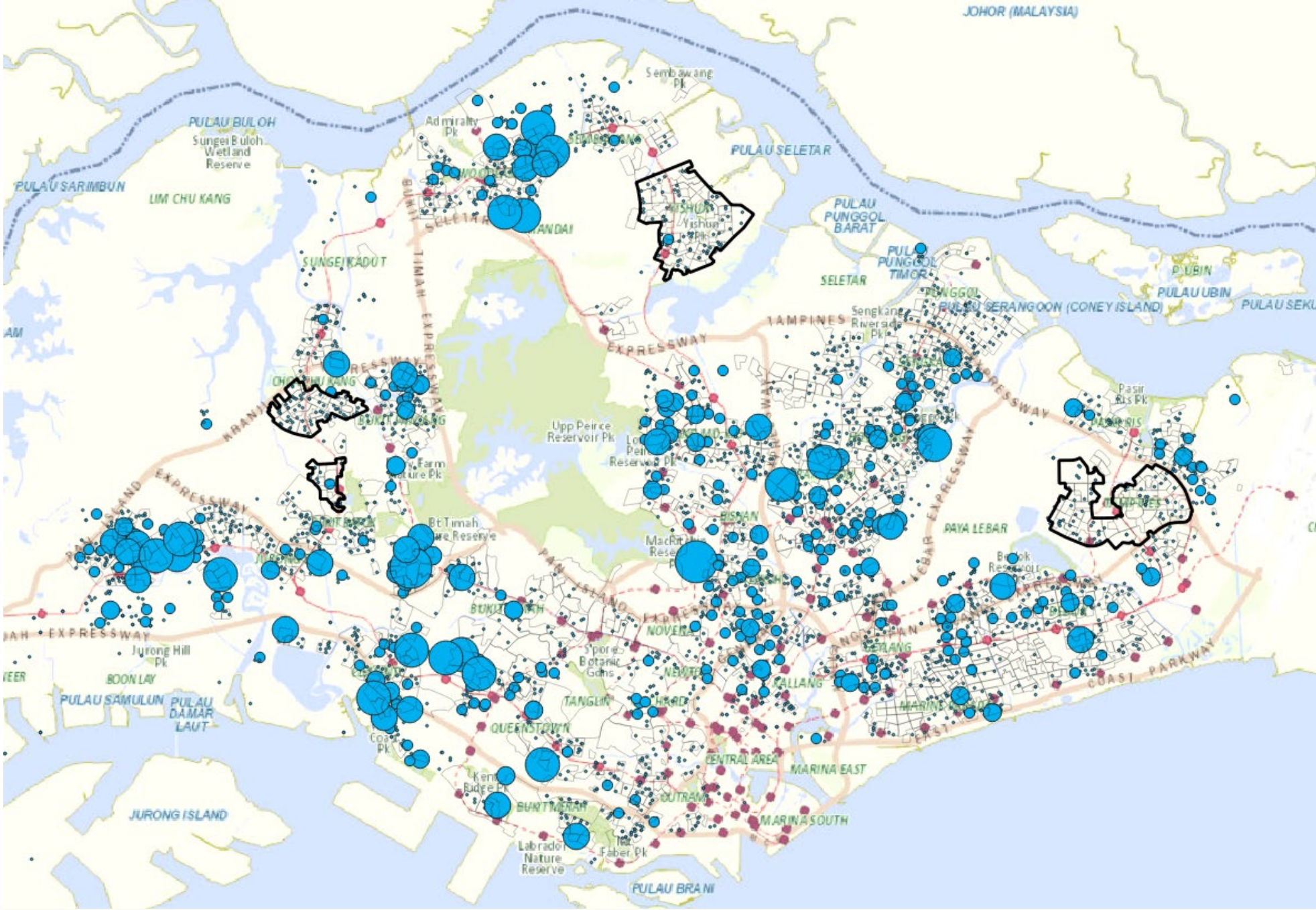
	Bukit Batok	Choa Chu Kang	Tampines	Yishun
3 months	54 (24-59)	35 (11-38)	38 (21-42)	68 (57-71)
6 months	57 (36-62)	32 (6-38)	37 (16-41)	69 (54-74)
12 months	**55** (24-61)	**36** (4-42)	**51** (42-57)	**77** (67-78)

Clusters in 2022 according to number of cases

- 2 - 10
- 10 - 44
- 44 - 88
- 88 - 175
- 175 - 392
- 392 - 531

HDB & Landed sectors

Wolbachia release sites



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Environmental Public Health Operations Group (Tony **Teo)**

Public Engagement Group (Yuin Chien **Lim)**

NUS-Alex Cook, NTU-Jue Tao Lim, MOH-Vernon Lee

Environmental Health Institute

WHO Collaborating Centre for Reference and Research of Arbovirus and their Associated Vectors

An Institute of

National Environment Agency

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