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Supplementary Materials for

Combining contact tracing with targeted indoor residual spraying significantly reduces dengue transmission

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This PDF file includes:

ascertain the locations visited while viremic and, ultimately, the most likely place of transmission (called “acquired where” in the form).

Supplementary Text

The Dengue Fever Management Plan (DFMP) for North Queensland

The operational objectives of the DFMP are (*27*): a) to recognize dengue cases as rapidly as possible through laboratory and clinical surveillance; b) to respond to dengue cases, with thorough and sustained vector control aimed at eliminating local transmission and preventing virus spread to other urban foci; c) to use a variety of education initiatives to maintain community awareness; d) to conduct preventive vector control actions in key premises like backpacker hostels and schools.

Diagnosis is performed at local laboratories using rapid immunochromatographic and enzyme-linked immunoassay (ELISA) tests to detect dengue IgM. All positive serum samples are forwarded to the reference laboratory where they are screened for the presence of anti-dengue IgM and IgG using a combined pool of flavivirus antigens in capture immunoassay (EIA). Positive IgM samples are further analyzed using flavivirus-specific IgM ELISA capture assays in order to identify the serotype of the infecting dengue virus (*52*). Additionally, real-time TaqMan reverse transcriptase-polymerase chain reaction is performed on samples collected early in the acute illness to detect dengue virus RNA (*53*).

Surveillance and control activities are dependent on the level of dengue activity (*27*). In the absence of local DENV transmission, laboratory surveillance is geared to detect imported cases. Once a locally-acquired case (i.e., an infected patient with no travel history) is confirmed, an outbreak is declared, even if only consists of a single case [the history of dengue fever outbreaks initiated by imported cases strongly supports this action (*27, 50*)]. The notification of either a dengue IgM positive test result or a suspected imported case triggers the initiation of emergency vector control activities.

Targeted indoor insecticide residual spraying (SC 2.5% lambda-cyhalothrin, Demand) and larval control/source reduction activities (turning over of small containers and treatment of large containers with S-methoprene pellets and residual surface sprays) are performed in premises within 100 meters of a confirmed case (*27*). If multiple DENV cases are reported in a particular area, the response zone is expanded to account for virus circulation. Field data is recorded in palm-top GPS receivers (Nomad, Trimble, Sunnyvale, CA) and then imported into a Geographical Information System (GIS) for mapping vector control response activities.

Location-based Contact Tracing

Notification of dengue infection and laboratory confirmation of all suspected cases are mandatory activities in North Queensland. Upon suspicion of a dengue case, doctors at any level are required to submit a form requesting sample processing as well as providing contact information (phone number) of each case (fig. S9). This form is immediately routed to Queensland Health public health nurses, who perform contact tracing telephonic interviews to determine a patient's travel history to identify the origin of infection (i.e., imported or locally acquired dengue), the date of onset of infection (i.e., the time a patient first started showing symptoms of dengue, minus 3 days), the locations a patient visited while viremic and, ultimately, the most likely place where infection has occurred (see fig. S10 for a sample of the interview

form). Contact tracing is performed on all suspected or confirmed dengue cases reported to the public health system. Interviews aim at obtaining information on the geographic location of a) home address, b) work address, and c) other places and people who a patient may have visited during the exposure period. Interviews were also performed with the persons each patient identified as potential primary or secondary contacts (e.g., work mates, relatives, friends) to pre-empt the detection of further secondary infections. This enhancement in the surveillance increases the detection of dengue infections that may not seek medical care under normal circumstances. Once interviews are completed, they are entered into a database with GIS capabilities that automatically geo-codes reported addresses and maps the location of each premise, interventions performed, and historical time series of cases. Control actions are deployed based on suspected and confirmed dengue cases, given the need to prevent epidemics from propagating throughout the city. Any addresses with recent (~10 days) dengue activity is considered a likely place of infection that needs to be targeted for control. The date and address for every IRS/source-reduction intervention are recorded in the database and linked to the Cairns GIS for mapping control progress.

Epidemic's Index Case Ascertainment

Initial DENV transmission activity in the neighborhood of Cairns North prompted public health nurses to conduct contact tracing phone interviews to identify the sources of infection and the likely index case of the epidemic (Fig. 3). Through interviews, nurses learnt that an immediate neighbor of those cases had recently returned ill from overseas. The neighbor was contacted and interviewed. He reported having been in Kalimantan Indonesia the month previous to the outbreak and had subsequently fallen ill upon return to Cairns (*45*). He did not seek medical attention. Clusters of DENV-3 cases were subsequently detected within 200 m of the potential index case's residence as well as around his mother's residence in Clifton Beach (located 22 km north of Cairns) where he also spent time. *Aedes aegypti* mosquitoes were found in both areas. At the request of Queensland Health, he subsequently submitted a blood sample that was IgM-ELISA positive for dengue. While it is possible that there were other unapparent infections, our exhaustive contact tracing and case identification suggest this is unlikely (*45*). Furthermore, there had not been an outbreak of DENV-3 in the Cairns region since 1998, and no known cases of DENV-3 were present in Cairns in the months leading up to the outbreak.

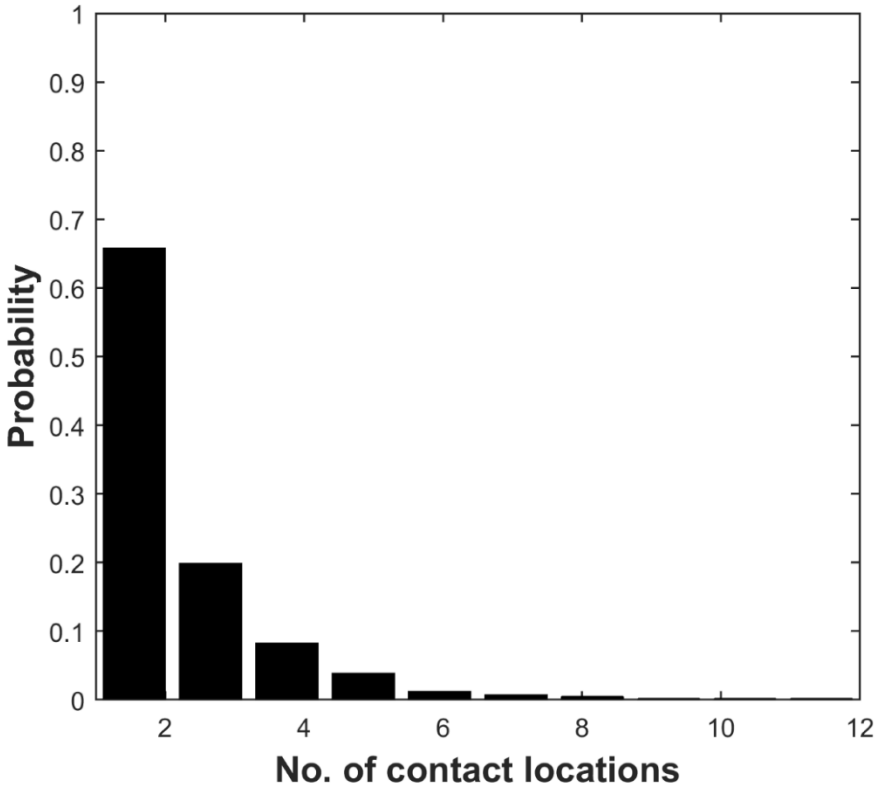


fig. S1. Distribution of contact locations (including the home residence) reported by each confirmed case of DENV.

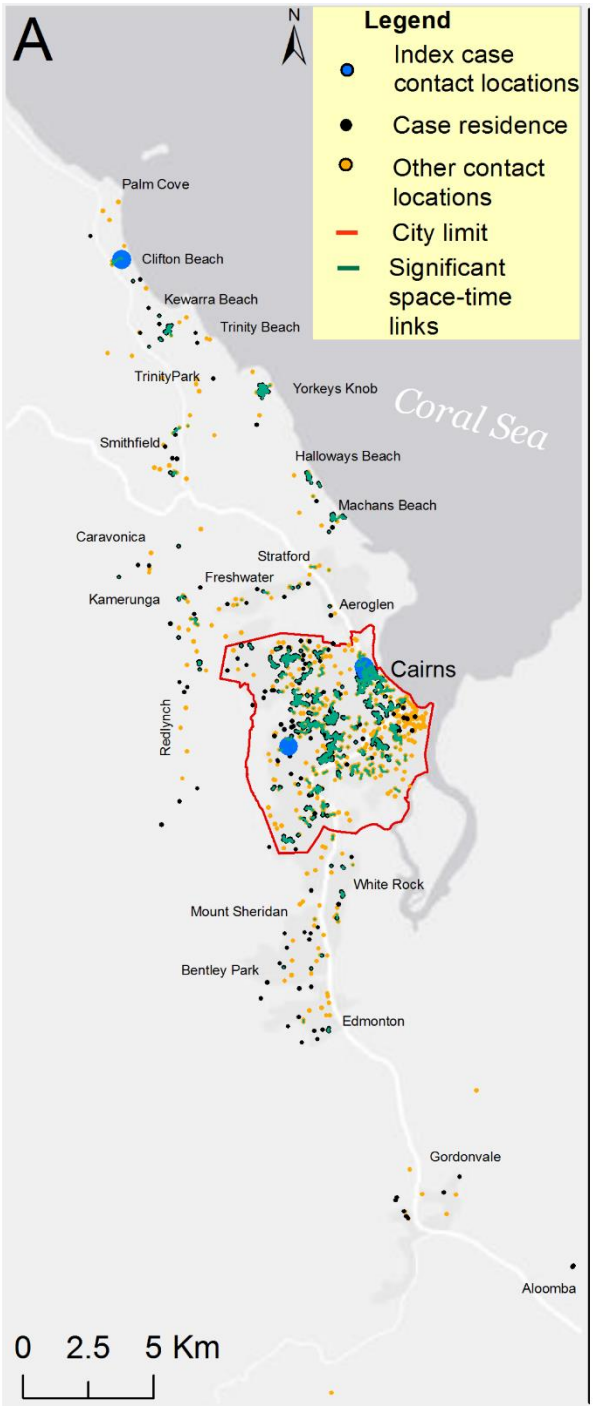


fig. S2. Results from local space-time interaction test, showing the contact locations and significant space-time links found within prespecified windows of 100 m and 20 days.

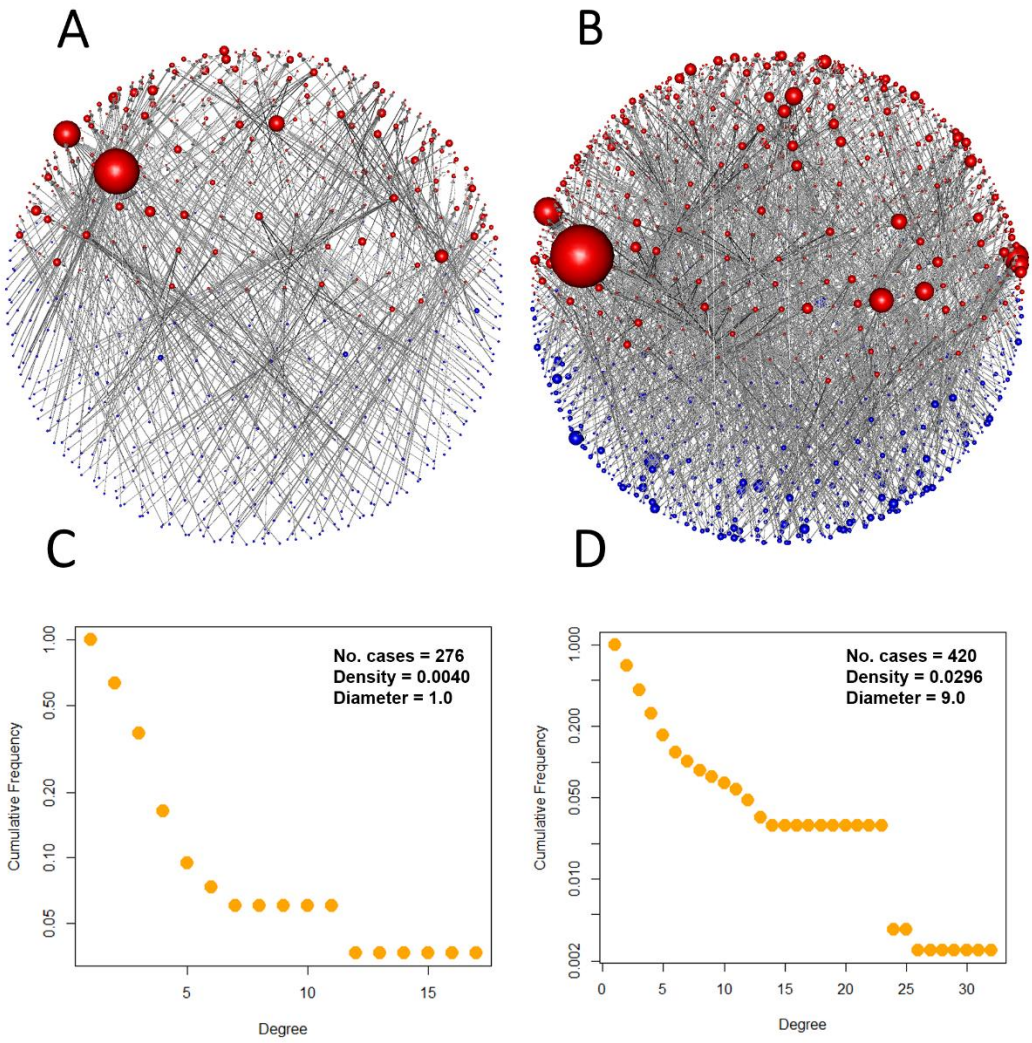


fig. S3. DENV transmission chains. Networks calculated using the home residence only (**A**) or the residence and contact locations (**B**) of all DENV cases confirmed in metropolitan Cairns (showed as a spherical layout with blue spheres for people and red spheres for spatio-temporally linked locations and size of spheres proportional to each sphere's number of connections). Large red sphere in graph is a multi-family housing unit. When looking at human cases alone (by joining cases spatio-temporally linked) we were able to estimate network metrics describing the degree of connectivity among cases within the 2008-2009 outbreak (e.g., degree distribution) for residences only (**C**) or residences and all reported contact locations (**D**). There are more individuals spatio-temporally linked when contact tracing data are analyzed in comparison to just using the residence. Specific network metrics included: degree distribution (cumulative probability distribution of the degree over the whole network.), density (the portion of the potential connections in a network that are actual connections) and diameter (shortest distance between the two most distant nodes in the network).

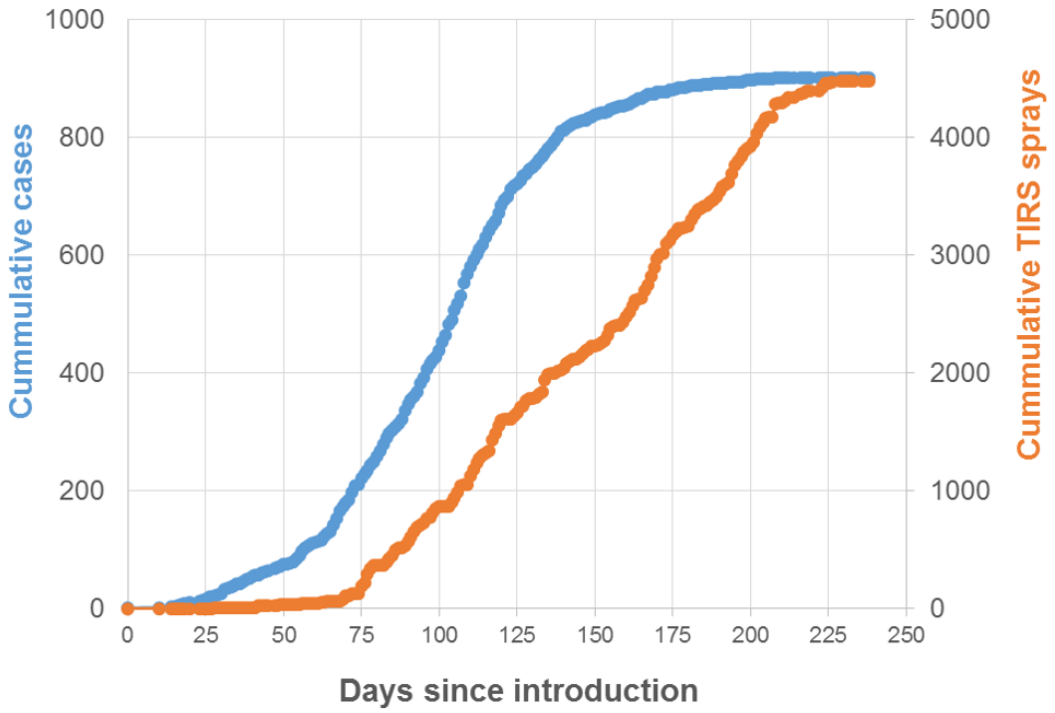


fig. S4. The cumulative number of confirmed symptomatic cases of DENV reported (blue) and the cumulative number of targeted indoor residual sprays performed (orange) during the 2008–2009 outbreak that affected the metropolitan Cairns area, Australia.

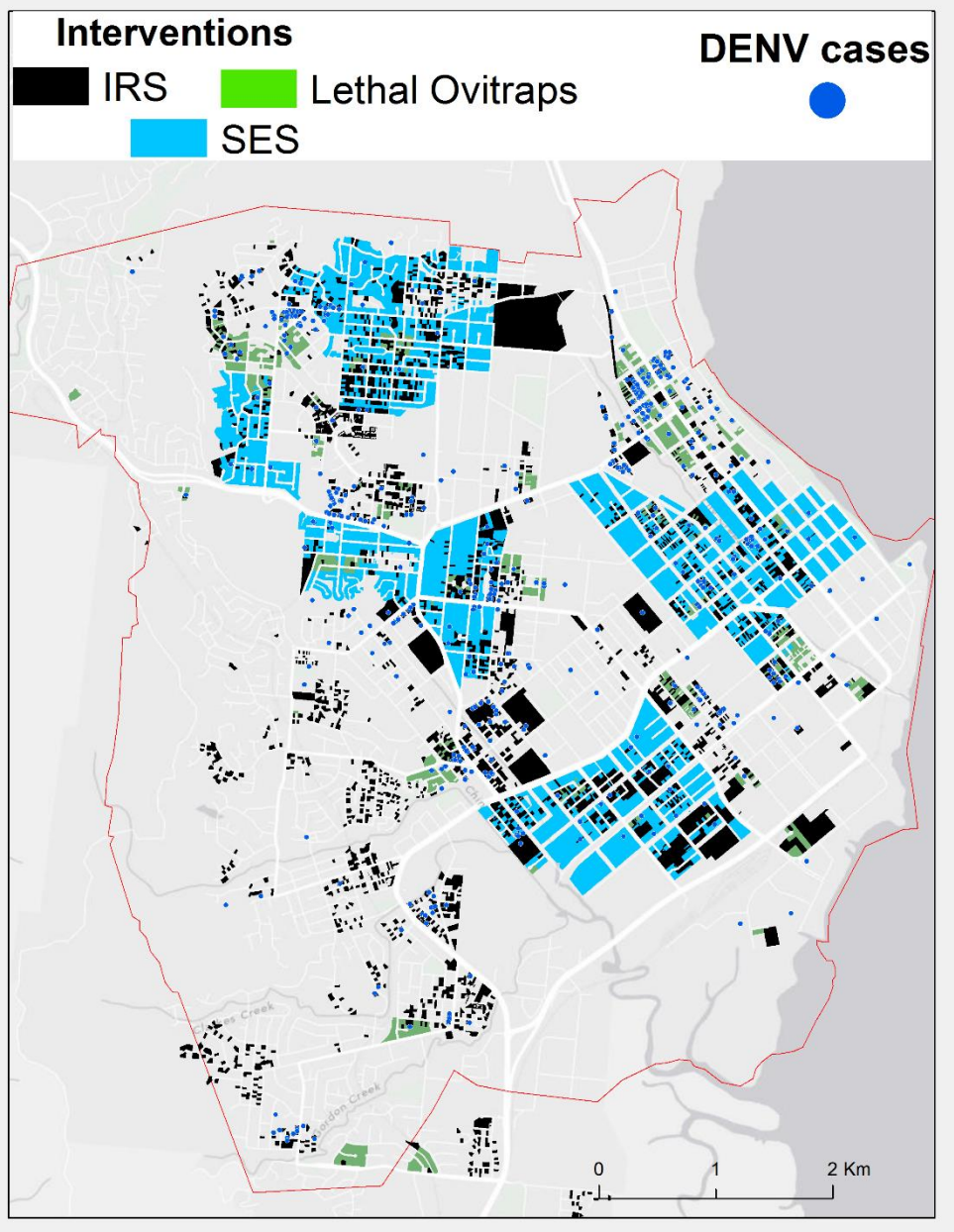


fig. S5. Distribution of interventions performed in Cairns in response to the 2009 DENV-3 epidemic: TIRS with pyrethroid insecticides, the placement of lethal *A. aegypti* ovitraps, and community education (State Emergency Service).

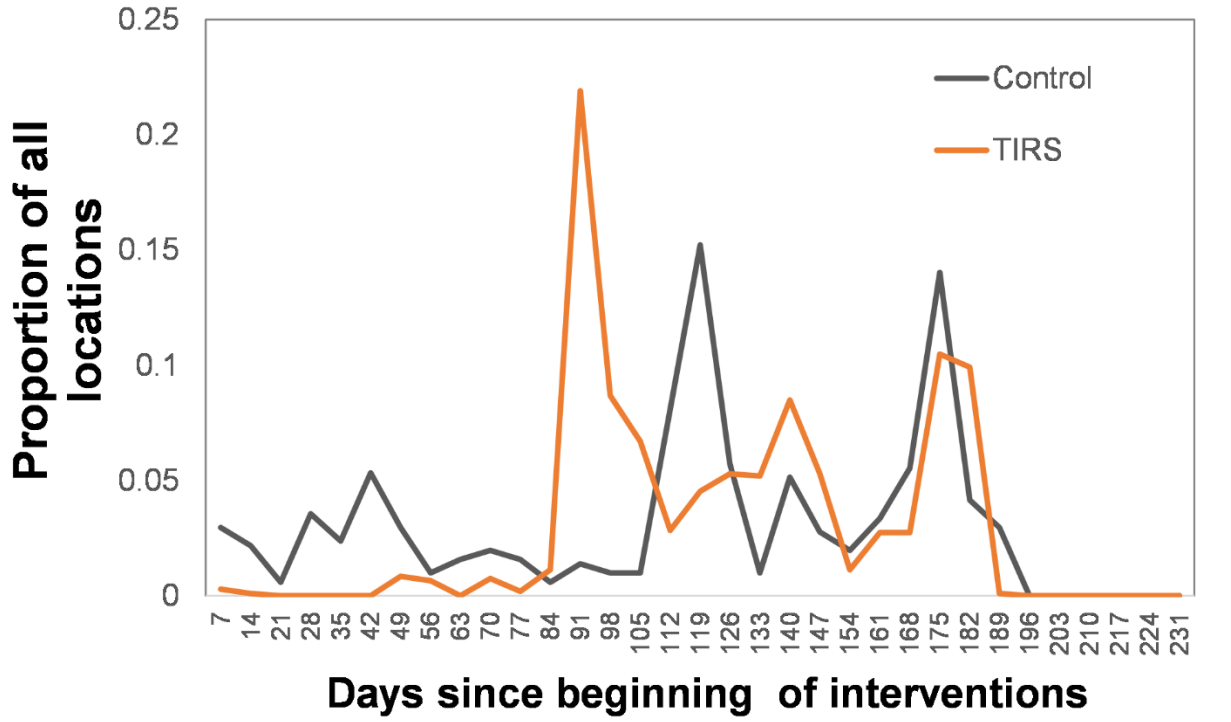


fig. S6. Temporal distribution of the number of locations analyzed in the Cox proportional hazards model evaluating the impact of TIRS on dengue transmission. TIRS indicates locations receiving residual insecticide applications, whereas controls are locations associated with dengue cases but not receiving an insecticide application. Data was selected considering the beginning of IRS applications in Cairns, which occurred 4 weeks post introduction of DENV.

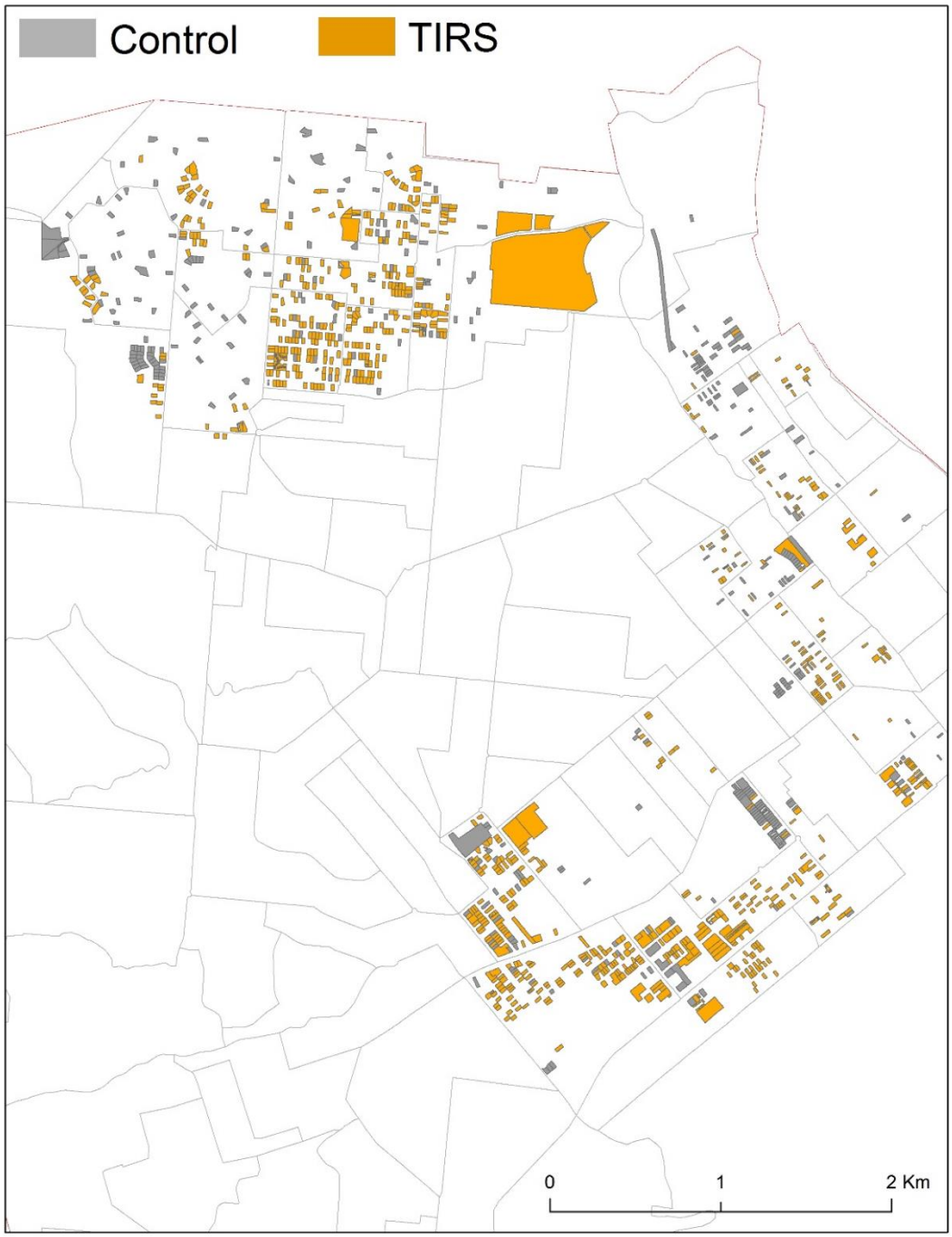


fig. S7. Spatial distribution of locations analyzed in the Cox proportional hazards model evaluating the impact of TIRS on dengue transmission. TIRS indicates locations receiving residual insecticide applications, whereas controls are locations associated with dengue cases but not receiving an insecticide application.

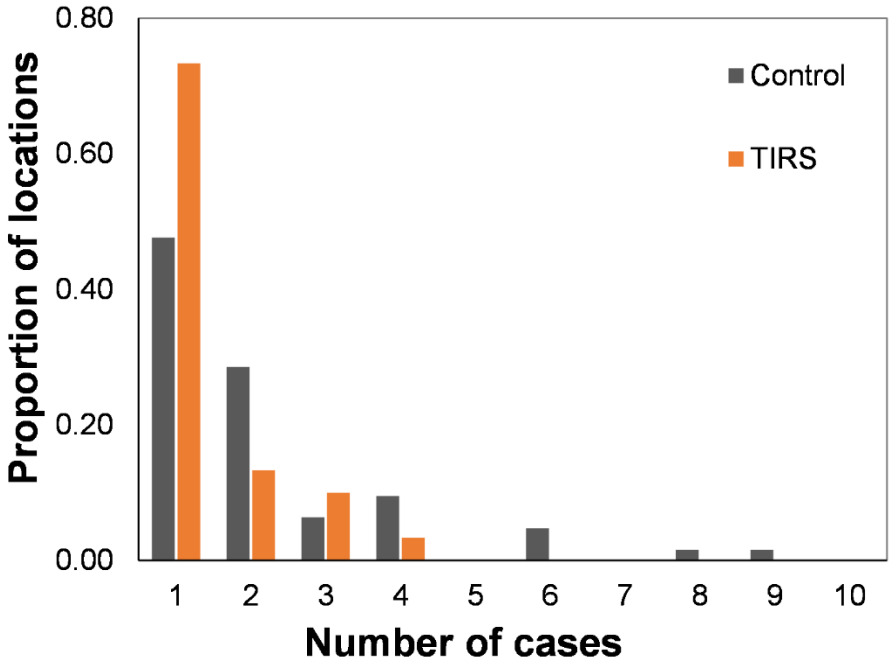


fig. S8. Number of secondary dengue cases spatiotemporally linked to locations TIRS-sprayed or not sprayed at all (control).

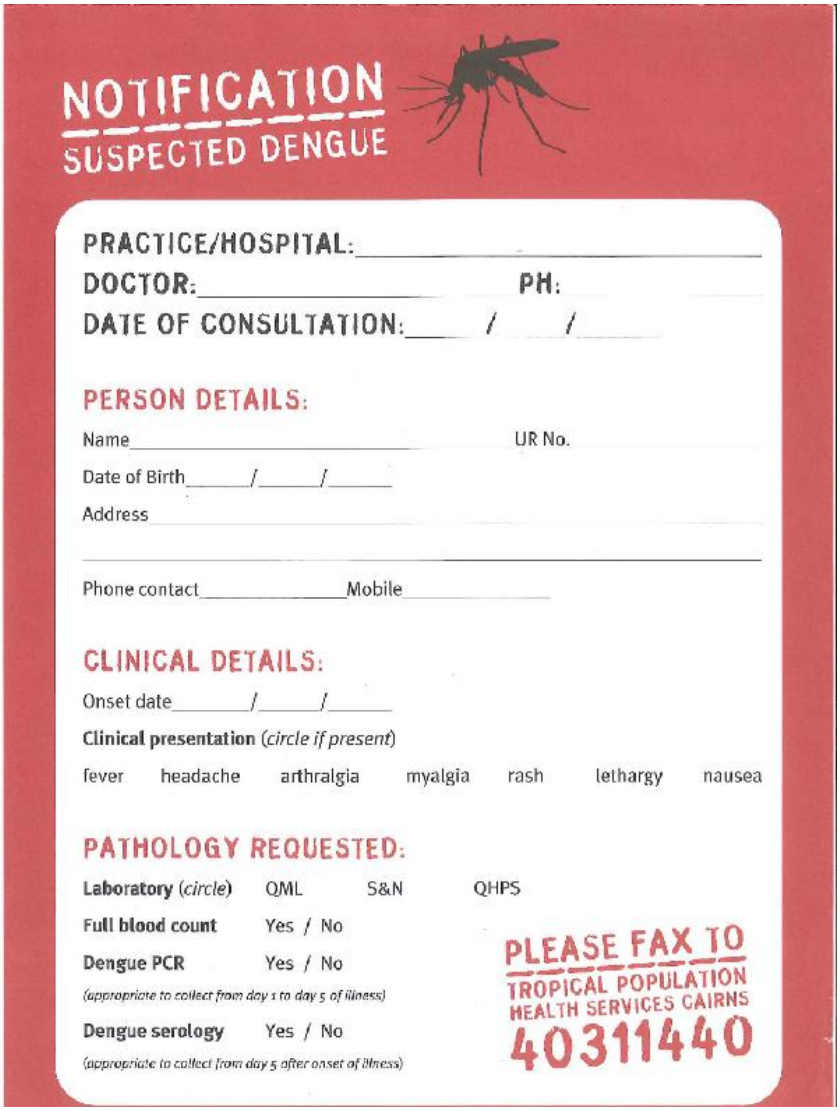
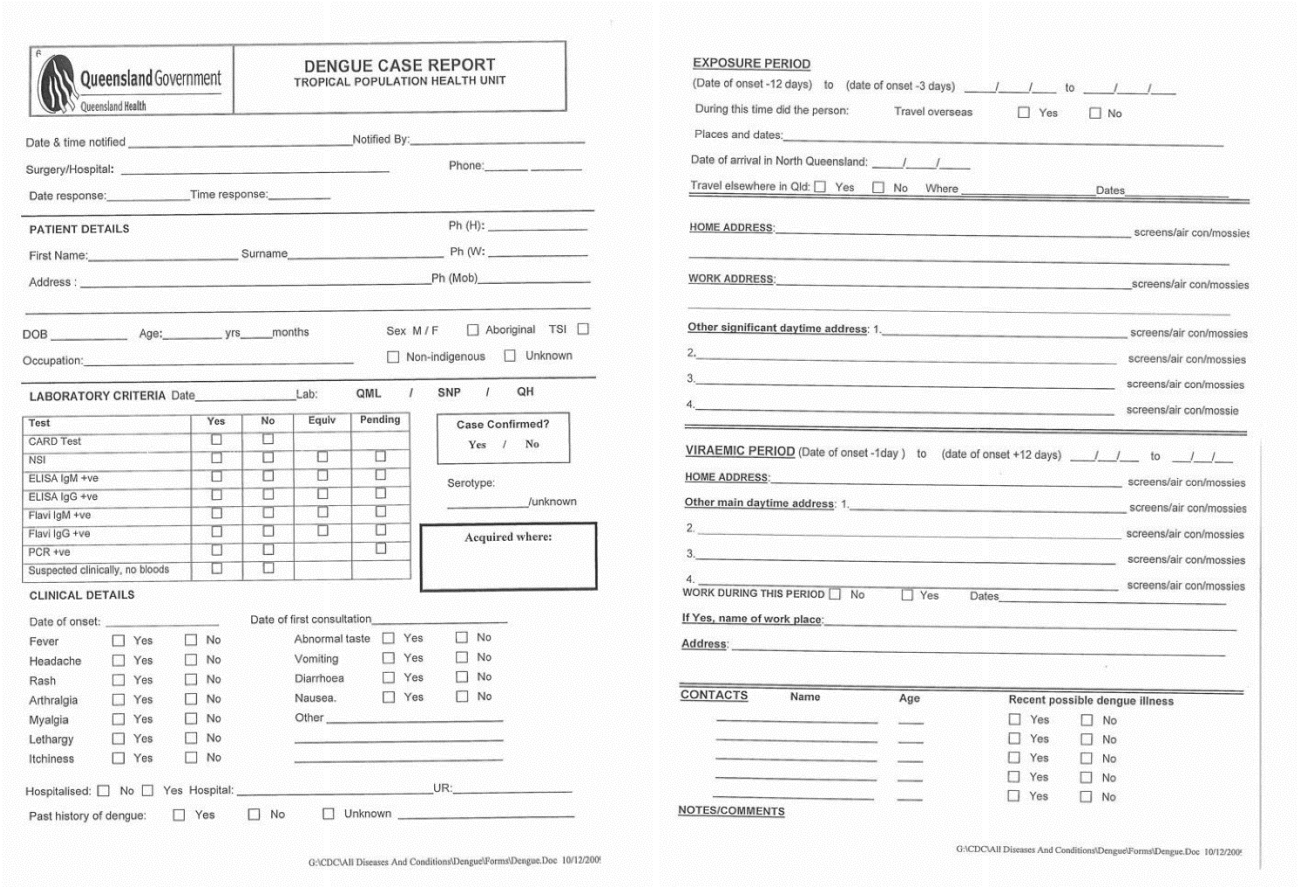


fig. S9. Form used by Queensland's medical general practitioners reporting suspected or confirmed cases to the Tropical Public Health Unit. Forms are submitted by fax and processed by TPHU's nurses immediately after receipt.



Queensland Government
Queensland Health

DENGUE CASE REPORT
TROPICAL POPULATION HEALTH UNIT

Date & time notified _____ Notified By: _____
Surgery/Hospital: _____ Phone: _____
Date response: _____ Time response: _____

PATIENT DETAILS
First Name: _____ Surname _____
Address : _____
DOB _____ Age: _____ yrs _____ months
Occupation: _____
Ph (H): _____
Ph (W: _____
Ph (Mob) _____
Sex M / F ☐ Aboriginal TSI ☐ ☐ Non-indigenous ☐ Unknown

LABORATORY CRITERIA Date _____ Lab: QML / SNP / QH

Test	Yes	No	Equiv	Pending
CARD Test	☐	☐		
NSI	☐	☐	☐	☐
ELISA IgM +ve	☐	☐	☐	☐
ELISA IgG +ve	☐	☐	☐	☐
Flavi IgM +ve	☐	☐	☐	☐
Flavi IgG +ve	☐	☐	☐	☐
PCR +ve	☐	☐		☐
Suspected clinically, no bloods	☐	☐		

Case Confirmed? Yes / No

Serotype: _____/unknown

Acquired where:

CLINICAL DETAILS
Date of onset: _____
Date of first consultation _____

Fever	☐ Yes	☐ No	Abnormal taste	☐ Yes	☐ No
Headache	☐ Yes	☐ No	Vomiting	☐ Yes	☐ No
Rash	☐ Yes	☐ No	Diarrhoea	☐ Yes	☐ No
Arthralgia	☐ Yes	☐ No	Nausea.	☐ Yes	☐ No
Myalgia	☐ Yes	☐ No	Other _____		
Lethargy	☐ Yes	☐ No	_____		
Itchiness	☐ Yes	☐ No	_____		

Hospitalised: ☐ No ☐ Yes Hospital: _____ UR: _____
Past history of dengue: ☐ Yes ☐ No ☐ Unknown _____

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EXPOSURE PERIOD
(Date of onset -12 days) to (date of onset -3 days) ____/____/____ to ____/____/____
During this time did the person: Travel overseas ☐ Yes ☐ No
Places and dates: _____
Date of arrival in North Queensland: ____/____/____
Travel elsewhere in Qld: ☐ Yes ☐ No Where _____ Dates _____

HOME ADDRESS: _____ screens/air con/mossies
_____
WORK ADDRESS: _____ screens/air con/mossies
_____
Other significant daytime address: 1. _____ screens/air con/mossies
2. _____ screens/air con/mossies
3. _____ screens/air con/mossies
4. _____ screens/air con/mossie

VIRAEMIC PERIOD (Date of onset -1day) to (date of onset +12 days) ___/___/___ to ___/___/___
HOME ADDRESS: _____ screens/air con/mossies
Other main daytime address: 1. _____ screens/air con/mossies
2. _____ screens/air con/mossies
3. _____ screens/air con/mossies
4. _____ screens/air con/mossies
WORK DURING THIS PERIOD ☐ No ☐ Yes Dates _____
If Yes, name of work place: _____
Address: _____

CONTACTS	Name	Age	Recent possible dengue illness
			☐ Yes ☐ No
			☐ Yes ☐ No
			☐ Yes ☐ No
			☐ Yes ☐ No
			☐ Yes ☐ No

NOTES/COMMENTS

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fig. S10. Dengue case report forms used by the Tropical Public Health Unit nurses to interview suspected or confirmed dengue cases (and their contacts) and ascertain the locations visited while viremic and, ultimately, the most likely place of transmission (called "acquired where" in the form).