Surveillance and Control of Dengue Vectors

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Surveillance and Control of Dengue Vectors

Aedes aegypti

Aedes albopictus

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Objective

Provide an overview and make recommendations on current and novel techniques for the surveillance and control of dengue vectors
Contents

• Dengue and other arboviruses
• Vector surveillance
• Vector control
• New tools
Dengue

- Dengue is caused by any one of various closely related dengue viruses (*Flaviviridae, Flavivirus*; DENV 1, DENV 2, DENV 3, DENV 4)
- The viruses are transmitted to humans by the bite of infected *Aedes (Stegomyia)* mosquitoes, mainly *Ae. aegypti* and *Ae. albopictus*
- Infection with one serotype does not protect against the others, and sequential infections put people at greater risk for dengue hemorrhagic fever (DHF) and dengue shock syndrome (DSS)
- The principal symptoms of dengue fever are high fever, severe headache, severe pain behind the eyes, joint pain, muscle and bone pain, rash, and mild bleeding (e.g., nose or gums bleed, easy bruising). Severe dengue includes persistent vomiting, severe abdominal pain, internal bleeding, difficulty breathing, failure of the circulatory system and shock, followed by death
- There are 390 million dengue infections per year, of which 96 million present some level of disease severity
- Mortality due to dengue can be less than 1%
Dengue in the world

Dengue in the USA

a. Endemic / epidemic dengue
   i. *Aedes aegypti* is present: **Puerto Rico, US Virgin Islands, and American Samoa**

b. Non-endemic – Risk for dengue emergence / re-emergence
   i. *Aedes aegypti / Ae. albopictus* are present: Southern areas of **Florida, Texas, Arizona, New Mexico, California**
   ii. *Aedes albopictus* is present: **Guam, Mariana Islands, and Hawaii**

c. Non-endemic – Lower risk areas
   i. *Aedes albopictus* is present: South Atlantic (Florida, Georgia, South Carolina, North Carolina, Virginia, West Virginia, Maryland, Delaware, Washington DC), Middle Atlantic (Pennsylvania, New Jersey, Connecticut, **New York**), East South Central (Mississippi, Alabama, Tennessee, Kentucky), West South Central (Louisiana, Oklahoma, Arkansas), and East North Central (Illinois, Indiana, Ohio)

d. No dengue vectors - Risk for dengue vectors invasions but their establishment is unlikely
   i. Pacific (Alaska, Washington, Oregon), Mountain (Montana, Idaho, Wyoming, Nevada, Utah, Colorado), West North Central (North Dakota, South Dakota, Minnesota, Nebraska, Iowa, Kansas, Missouri), and East North Central (Wisconsin, Michigan)

   **In bold:** recent autochthonous dengue transmission
Recent, autochthonous DENV circulation in the US - 2013

- Florida (Martin County 22 cases; Miami-Dade Co. 1 case)
- Southern Texas (Cameron Co. and Hidalgo Co. 12 cases)
- New York (Suffolk Co., 1 case)
- Puerto Rico (17,153 cases)
Reported *Aedes aegypti*

Reported and predicted *Aedes albopictus*
Other, emerging arboviruses: Chikungunya virus (*Togaviridae, Alphavirus*)

- Chikungunya virus infection can cause a debilitating illness, most often characterized by fever, headache, fatigue, nausea, vomiting, muscle pain, rash, and joint pain (similar to dengue)
- The virus is transmitted to humans by the bite of infected *Ae. aegypti* or *Ae. albopictus*
- Chikungunya virus infection is thought to confer life-long immunity
- Fatalities related to chikungunya virus are rare
- There is no vaccine or specific antiviral treatment currently available for chikungunya or dengue fever
CHIK virus is spreading (originally from Africa)

Autochthonous CHIK transmission is occurring for the first time in the Americas (December 2013; St. Martin, Martinique, Guadeloupe, St. Barthélemy, Jost Van Dyke islands in the Caribbean)

It is likely to spread to the rest of the American countries where Ae. aegypti and Ae. albopictus are common

Urban CHIK and dengue have similar ecologies

http://www.cdc.gov/chikungunya/map/index.html
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Main dengue vectors

**Aedes aegypti**

- African treehole mosquito
- Closely associated with people
- Does not depend on the presence of vegetation
- Indoor / outdoor (resting, biting, ovipositing)
- Urban/suburban/rural areas
- Greater resistance to desiccation (eggs)
- Main dengue vector worldwide

**Aedes albopictus**

- Asian treehole mosquito
- Less dependent on people
- Depends on tall vegetation
- Outdoor mosquito
- Suburban/rural areas
- Main dengue vector in some areas / secondary
- Greater cold hardiness
- Better competitor in larval stage
Where *dengue vectors* develop?

Water-storage containers
Utensils (pails, tarps)
Discarded containers (trash)
Recreation objects (plastic pools, toys, boats)
Ornamental (fountains, plant pots)
Animal drinking pans
Septic tanks
Water meters
Area-wide vs. focal surveillance and control of dengue vectors

• Area-wide refers to the population of mosquitoes (eggs, larvae, pupae, adults) living in a given area
  – Surveillance implies monitoring the whole population in space and time
  – Control implies managing the whole population to keep it below transmission levels or to eliminate the population

• Focal refers to spotty or partial following up and control of mosquitoes
  – Surveillance and control are done in response to complaints or focal transmission of arboviruses
Vector surveillance

• It is about detecting and counting mosquitoes
  – How many are there, where, when?
  – How reliably? (how many samples?)
• To detect new species introductions
• To monitor:
  – Elimination efforts (mosquito presence / absence)
  – Control efforts (mosquito abundance)
Surveillance of immature stages

- Involves locating containers and examining their contents:
  - Single-larva surveys (Sheppard et al. 1969)
  - *Stegomyia* indices (house, Breteau, container indices)
  - Pupal surveys (e.g., Focks & Chadee 1997)
Single-larva surveys (Sheppard et al. 1969)

- A single larva is collected / identified per container (instead of all or many larvae)
- When the first larva of *Aedes* is found, there is no need to continue searching at that house
- Provides:
  - Presence / absence data per mosquito species
  - Percentage of houses positive for *Ae. aegypti*
- Does not provide: Co-occurrence with other species present
- Allows surveying larger areas / use less personnel
Surveillance using *Aedes (Stegomyia) indices*

- Most widely used
- Presence / absence data (derived indices; House, Breteau, Container indices)
- Assume most aquatic habitats of *Ae. aegypti* are in households
- Rely on visual search of containers with water and immatures
- Requires a relatively small sample size (100 – 200 houses)
- Bear a poor relationship with adult mosquitoes or dengue
Pupal indices

- # pupae more related to # adult mosquitoes
- Provide absolute measure of population density (e.g., pupae/hectare)
- Rely on visual search of containers with water and immatures
- Allow identification of most productive containers and targeted control
- However, require large sample sizes for reliable estimation (1000 – 3000 houses)
- Pupal surveys can be simplified (e.g., Barrera 2009)
Limitations of immature surveys / control

• Reliance on finding aquatic habitats by visual inspections of houses / public areas
• Presence of cryptic, highly productive aquatic habitats is an increasingly common finding
  – Nigeria (septic tanks; Irving-Bell et al. 1987)
  – Australia (service man holes and pits, wells, mines, septic tanks, storm drains, sumps, roof gutters; Kay et al. 2000; Russell et al., 2002; Montgomery & Richie 2002)
  – Colombia (storm drains throughout the city; Gonzalez & Suarez 1995)
  – Puerto Rico (septic tanks, water meters; Barrera et al. 2008)
  – Brazil (elevated water tanks, roof gutters and water holding roofs; Pilger et al. 2011)
  – Mexico (storm drains, catch basins; Manrique-Saide et al. 2012)
Recommendations (Immature surveillance)

• Immature surveillance is necessary to determine the types of containers producing *Aedes* spp., which ones are the most productive, and to derive specific control strategies (e.g., tire recycling)

• Monitoring changes of the population of container *Aedes* through immature surveillance may not be efficient / sustainable as compared with adult mosquito surveillance

• Bear in mind the possibility of existing cryptic aquatic habitats (in particular if traditional control is failing)
Adult mosquito surveillance

- **Ovitraps** (presence / absence; eggs/trap; Fay and Eliason 1966, Reiter et al. 1991; Barrera et al. 2013a)
  - Useful to detect container *Aedes* mosquitoes
  - Track gravid females (important from transmission point of view)
  - Inexpensive, easily deployed – not invasive
  - Might be influenced by availability of other aquatic habitats – particularly after control efforts
  - Requires some effort / training to count eggs
  - Very commonly used in vector control programs
  - Sampling can be simplified (empirical relationship between eggs / ovitrap and % positive traps; Mogi et al. 1990)
  - May be more useful than realized
Adult mosquito surveillance

– Landing counts (not recommended if there is dengue transmission)

– Aspiration techniques (Clark et al. 1994, Vazquez-Prokopec et al. 2009)
  • Require much labor
  • Gives measure of absolute population density
  • Sample size > 200 houses

– Former adult traps (Fay & Prince 1970)
  • Bulky, heavy, difficult to deploy in sufficient numbers in field
  • Expensive

Fay and Prince trap
Adult mosquito surveillance (cont...)

- **Adult traps**
  - **Newer traps**
    - BG-Sentinel (Kroekel et al., 2006) - A
    - Adult trap (Gomez et al. 2007) - B
    - Gravid Aedes trap (GAT; Eiras et al. 2014) - C
    - Sticky gravid traps
      - Double sticky trap (Ritchie et al. 2003, Chadee & Ritchie 2010) - D
      - MosquiTrap (Eiras 2000) - E
      - Facchinelli’s et al. 2007 - F
      - CDC Autocidal Gravid Ovitrap (CDC-AGO; Barrera et al. 2013; Mackay et al. 2013) - G
BG-Sentinel traps

• Track most stages of adult Ae. aegypti and Ae. albopictus
• Can be deployed in sufficient numbers for reliable estimations (compared to Fay & Prince traps; Williams et al. 2007)
• Useful to track spatial and seasonal changes (e.g., Barrera et al. 2011a, b)
• Expensive (trap, batteries, lure)
• Black BG traps captured more Ae. aegypti, Ae. mediovittatus and Cx. quinquefasciatus in the field and laboratory than white BG traps

Barrera et al. 2013b
Passive, sticky gravid traps

• Target ovipositing females
• Some are inexpensive, easy to deploy
• Provide a direct assessment of gravid females as compared to ovitraps
• Depending on model require more / less labor
CDC Autocidal, gravid ovitrap (CDC-AGO)

No maintenance for up to 2 months
Comparing captures of *Ae. aegypti* females in BG and CDC-AGO traps

Correspondence in captures between BG-Sentinel and CDC-AGO traps is significant (Barrera et al. 2014)
Trends in container *Aedes* surveillance

- Vector surveillance relied mostly on the use of immature indices because it was very difficult to monitor the adult mosquito population
- New traps for adult *Aedes* (BG, gravid traps) allow better surveillance (adult mosquitoes transmit viruses)
- It is easier, and perhaps will motivate, evaluating the impact of control measures
- Facilitate ecological studies
- Some dengue control programs are adopting ovitraps as their main surveillance strategy (e.g., Mexico)
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Dengue vector control

• Vector elimination – in recently invaded areas (e.g., California) – requires very reliable surveillance and area-wide vector management

• Vector control to prevent dengue virus transmission
  – Thresholds are not well established – they change with human population immunity (lower immunity – fewer mosquitoes / person) and temperature (higher temperatures – fewer mosquitoes / person; Focks et al. 2000)
  – More research is needed to determine practical thresholds
Mosquito Control

– Control of immature mosquitoes
  • Source reduction / protection
    – Environmental management
  • Larvicides
  • Biological control

– Control of adult mosquitoes
  • Adulticides
    – Spatial spraying
    – Residual applications (indoor / outdoor)
    – Insecticide-treated materials (ITMs)
      » Lethal ovitraps
      » Curtains / covers
    – Gravid traps
  • Personal protection
    – Repellents
    – Clothing

– Sanitary education
– Community involvement
Environmental management of artificial containers I

Household Level

– Make householders aware of life cycle of container mosquitoes

– Promote:
  • Keeping clean, tidy yards
  • Servicing water storage containers (brush, detergent, and bleach) and keeping them tightly closed
  • Not to keep plants in water but soil
  • Servicing domestic animals’ water-pans / bird baths frequently
  • Keeping septic tanks sealed / screened
Environmental management of artificial containers II

Community Level (County, District, etc.)

– Organize:

• Sound pick-up and disposal of solid waste (including large items / junk)
• Recycling programs (tire, garbage)
• Adequate and reliable supply of potable water
• Removal of artificial containers in public areas (alongside streams, abandoned lots, tire piles)
• Planting ornamental trees that do not form cavities where water accumulates
• Training of gardeners / landscape contractors / landlords / other maintenance personnel on the lifecycle / control of container mosquitoes
Mosquito Control

– Control of immature mosquitoes
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  • Biological control

– Control of adult mosquitoes
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  • Personal protection
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    – Clothing

– Sanitary education
– Community involvement
Larviciding:
Application of chemicals or bio-pesticides to kill mosquito larvae or pupae by ground or aerial treatments

- Temephos (organophosphate insecticide)
- Bio-rational larvicides or bio-pesticides
  - *Bacillus thuringiensis israelensis* or B.t.i., a bacterial larvicide
  - Spinosad (new mode of action) – newly applied to vector control
  - Insect Growth Regulators
    - Juvenile hormone analogs
      - Methoprene
      - Pyriproxifen (very low concentration IGR) – recent addition
    - Chitin synthesis inhibitors
      - Diflubenzuron
      - Novaluron
- Monomolecular films and Oils
Mosquito Control

– Control of immature mosquitoes
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    – Environmental management
  • Larvicides
  • Biological control

– Control of adult mosquitoes
  • Adulticides
    – Spatial spraying
    – Residual applications (indoor / outdoor)
    – Insecticide-treated materials (ITMs)
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  • Personal protection
    – Repellents
    – Clothing

– Sanitary education
– Community involvement
Biological control

- **Predators**
  - Larvivorous fish
  - Dragonfly larvae
  - Other, predatory insects (e.g., *Toxorhynchites*)
  - Copepods

- **Pathogens**
  - Microsporidia (*Edhazardi aedis*)
  - Fungi (e.g., *Laegenidium giganteum*)
Mosquito Control

– Control of immature mosquitoes
  • Source reduction / protection
    – Environmental management
  • Larvicides
  • Biological control

– Control of adult mosquitoes
  • Adulticides
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    – Insecticide-treated materials (ITMs)
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    – Gravid traps
  • Personal protection
    – Repellents
    – Clothing

– Sanitary education
– Community involvement
**Adulticiding: outdoor spatial applications**

**Insecticides:** Organo-phosphates (e.g., malathion), Pyrethroids (e.g., permethrin, resmethrin), Carbamates

Ultra-low volume (ULV) spatial application of non-residual insecticides targeting adult mosquitoes (very small drops of insecticide)

- Various applications 2-3 per week required
- Kills 88% of male and 30% of female *Ae. aegypti* after repeated applications (every 12 h for 5.5 days; Focks et al. 1987)
- Effective on *Ae. albopictus* for temporary suppression, even if applied at night (Farajollahi et al. 2012)
- Short-lived effect (does not affect immature production)
- Mosquitoes inside houses largely unaffected by truck or airborne applications
- It is not recommended as a tool to manage the *Aedes* population but to intercept and kill infected mosquitoes

**Hand Held**

**Truck-mounted**

**Aircraft**
Adulticiding: indoor spatial applications

Ultra-low volume (ULV) spatial application indoors

• Provided temporary suppression of *Ae. aegypti* in Iquitos, Peru after 6 weekly applications (A. Morrison, pers. comm.) and a possible impact on dengue transmission
• Mosquito populations recover initial levels soon after
• It is thought to be useful to temporarily interrupt dengue transmission
• It requires lots of personnel and equipment
• Truck-mounted equipment and long hoses could be used instead of, or to complement backpack applications
Adulticides: Residual applications

– Indoor application of residual insecticides
  • Short residual effect of current insecticides (as compared with DDT)
  • Difficult to apply in certain settings (public acceptability)

– Barrier / resting site, outdoor residual insecticide application
  • Targets containers and other resting places outdoors
  • It has been shown to be effective against *Ae. albopictus* (e.g., Trout et al. 2007)
  • Because *Ae. aegypti* is mostly an outdoor mosquito in the US, barrier applications should also work for this species
Mosquito Control

- Control of immature mosquitoes
  - Source reduction / protection
    - Environmental management
  - Ovicides
    - Autocidal ovitraps
  - Larvicides
  - Biological control
- Control of adult mosquitoes
  - Adulticides
    - Spatial spraying
    - Residual applications (indoor / outdoor)
    - Insecticide-treated materials (ITMs)
      » Lethal ovitraps
      » Curtains / covers
    - Gravid traps
  - Personal protection
    - Repellents
    - Clothing
- Sanitary education
- Community involvement
Personal protection (limits access to human blood and prevents infections)

Repellents (DEET, picaridin, IR3535, and oil of lemon eucalyptus and para-menthane-diol products)

Protective clothing

Screens
Mosquito Control

– Control of immature mosquitoes
  • Source reduction / protection
    – Environmental management
  • Ovicides
    – Bleach formulation
    – Autocidal ovitraps
  • Larvicides
  • Biological control

– Control of adult mosquitoes
  • Adulticides
    – Spatial spraying
    – Residual applications (indoor / outdoor)
    – Insecticide-treated materials (ITMs)
      » Lethal ovitraps
      » Curtains / covers
    – Gravid traps
  • Personal protection
    – Repellents
    – Clothing

– Sanitary education
– Community involvement
Health education I

- Vector-borne diseases are very difficult to understand or explain because they involve multiple organisms (host – pathogen – vector) and the environment.
- Education is better achieved with demonstrations of the mosquito life-cycle and with guided observations of mosquito immatures in containers in/around the house.
- Explicit, well illustrated, attractive audio-visual resources are preferred tools.

Mosquito development kit
Health education II

• Information / knowledge is not enough to promote a consistent behavior to prevent the production of mosquitoes
• People are unaware of the actual health problems of the community (do not manage epidemiological data)
• People are unaware that mosquitoes they produce may cause severe disease or death to their kin and neighbors
Mosquito Control

– Control of immature mosquitoes
  • Source reduction / protection
    – Environmental management
  • Ovicides
    – Bleach formulation
    – Autocidal ovitraps
  • Larvicides
  • Biological control

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– Sanitary education
– Community involvement
Community involvement

• Dengue is nearly impossible to control without the active involvement of the community - vectors are produced in or around premises and in communal areas
• Many community-based mosquito control programs fail in sustainability
• Community-based mosquito control programs must be an integral component of every day's Mosquito Control Programs
Why dengue vector control is not so effective?

• EGGS
  – The eggs of dengue vectors can resist desiccation for many months
  – There are no commercial ovicides – egg elimination is almost never done
  – Dengue vector populations are extremely resilient – capacity to recover from disturbances – because of this adaptation
  – Current larvicides do not last long enough to kill larvae hatching from eggs after several weeks / months
  – During the eradication campaign this was not so much of an issue because DDT inside containers lasted longer than eggs
• **Larvae and pupae**
  - The most common vector control measures are source reduction and larviciding
  - Eliminated, trash containers may re-appear within 3 months
  - Larvicides act for only a few weeks or less (e.g., people dump the temephos applied to their water-storage containers)
  - Larvae undergo density dependent regulation due to lack of food and competition in small, oligotrophic containers – so not killing all the larvae in a container (e.g., resistance to insecticides) will actually favor vector population increase
  - Dengue vector populations are rather resistant to crowding – contest competition - whereby some adults will always emerge from crowded containers
Why source reduction / larviciding may not be effective (fails achieving area-wide control)

Example: Source reduction and larviciding applied to a community by inspecting and treating houses

- If 30% of houses are closed or refuse treatment = only 70% of dengue vectors can be controlled
- If source reduction / larviciding is 80% effective (insecticide resistance, people dump the treated water, etc.) = then only 56% of vectors can be controlled (.7 x .8)
- If for various reasons an additional 20% is lost due to treatments that were not actually made (lack of effective supervision), overlooked containers, etc. = then only 45% of vectors would be controlled (.56 x .8)
- Thus, immature control can easily miss the target and the vector population can rapidly re-colonize the area
- It is necessary to evaluate the impact of immature control on the adult mosquito population rather than using immature indices – Vector control programs need to adapt work schedules to increase coverage – weekends / holidays
Further limitations

• Current control of adult dengue vectors is mostly limited to spatial spraying of insecticides (e.g., ULV), which has a transient effect and limited coverage (most adult mosquitoes rest inside houses)
• Residual spraying is not commonly used or accepted
• Early genetic control applications (reciprocal translocations) failed to control *Ae. aegypti* – the level of male sterilization (64%) may have been compensated by density-dependence in the larval stage leading to no effective population change (fewer larvae but similar # of pupae) – higher adult mortality / sterility would be required (McDonald et al. 1977)
• There might be other density-dependent effects in *Ae. aegypti*, such as increased female adult mortality while attempting to feed on people (defensive behavior) – so eliminating gravid adult females would be indicated
Dengue vector control recommendations

- Conduct pupal surveys to establish where mosquitoes are being produced and which ones produce the most – container composition may be site specific
  - Develop container/ site specific control measures
    - Source reduction (clean-up campaigns, recycling, improve garbage collection, etc.)
    - Protection (e.g., mosquito-proof water-storage containers)
    - Egg removal + long-lasting larvicide
    - Apply residual insecticide on / around containers and in nearby resting sites (monitor insecticide resistance and rotate products)
  - Make sure adequate coverage is achieved at the time of applying control measures (>90% of premises; work on weekends and holidays, widely inform the community ahead of time)
  - Evaluate the impact of immature control using adults as indicators before and after control – failing to control the adult population may indicate the presence of cryptic aquatic habitats
Dengue vector control recommendations (Cont.)

• Keep monitoring the adult mosquito population to:
  – Determine the duration of control
  – Detect hot spots or super-producers
    • Follow up using a basic Geographical Information System / maps and adult traps that produce readily available or almost real-time data from the field
  – Examine the relationship between adult mosquitoes and weather (e.g., accumulated rainfall during previous 2-3 weeks)
• Intensify control operations early in the season (cooler / drier) to prevent or slow down virus transmission later on
• Keep the communities informed about your progress / difficulties – provide information on what is expected from residents
• Spatial spraying of insecticides may be used to:
  – Eliminate particularly heavy infestations / complaints
  – Eliminate adult mosquitoes carrying the viruses
  – If there are indoor mosquito populations, combine indoor / outdoor spraying
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New Tools

• Eggs
  – Chlorine bleach formulation (CDC – smectite clay mix)
  – Autocidal ovitraps

• Larvae
  – Spinosad
  – Pyriproxyfen (PPF)
    • Auto-dissemination stations

• Adults
  – Insecticide treated materials (ITM)
    • Lethal ovitraps
    • Curtains
    • Covers for water storage containers
  – Sticky gravid traps (CDC-AGO trap)
  – Transgenic control - Release of Insects carrying a Dominant Lethal gene (RIDL)
    – Genetically Modified Mosquitoes (GM)
  – Para-transgenic control - Wolbachia-infected mosquitoes
    • Population modification
    • Population suppression
Ovicide formulation
(Chlorine bleach + smectite clay – thickening agent)

CDC, in preparation
Auto-dissemination of pyriproxyfen

- Renewed interest in the application of this delivery system
- It was initially proposed for *Aedes aegypti* (Itoh et al. 1994; Devine et al. 2012) and *Ae. albopictus* (Caputo et al. 2012; Gaugler et al. 2012)
- Need to evaluate its impact on a variety of containers
- May potentially deliver sub-lethal doses, which may cause resistance
Non-insecticidal ovitraps

CDC Polyacrylamide autocidal ovitrap
(eggs do not hatch / larvae desiccate on gel)
Barrera et al. 2013a

Mechanical autocidal ovitrap
(larvae suffocate; Chan et al 1972)
Insecticidal, lethal ovitraps (LOT; Perich et al. 2003)

- Perich-Zeichner’s LOT
- Small plastic cup, water, residual insecticide
- Kills ovipositing females and larvae
- Needs weekly servicing
- May become aquatic habitats
- May promote resistance to insecticides
Biodegradable lethal ovitrap (Ritchie et al. 2008)

- Bucket 700 ml water
- Thermoplastic starch polymers
- Insecticide (Bifenthrin 0.1%)
- Rapidly degrades (2 weeks)
Attractive Lethal Oviposition Traps – ALOTs (Wesson et al.)

• Targets gravid females of *Aedes aegypti*
  – Uses an attractant (bacterial cocktail)
  – An adulticide (kills females on contact; pyrethroid)
  – A larvicide (spinosad; prevents production of adult mosquitoes)
  – Are being tested to control dengue in Iquitos, Peru
Insecticide Treated Materials (ITMs): Curtains and covers for water-storage vessels (Kroeger et al. 2006)

- Material impregnated with residual insecticides
- They are being tested in several countries
- Gathering evidence on effectiveness
- Covers impregnated with DDT were first used in Guam in 1945 to control *Ae. aegypti* (Bailey and Bohart 1952)
CDC Autocidal Gravid Ovitrap (AGO)

- Trap gravid females of *Ae. aegypti*
- Do not use insecticides
- Larger volume of hay infusion bait = more attraction = longer action (less maintenance)
- Larger entrance with black capture surface
- All black exterior
- ¾” exclusion screen
- Serviced every two months
Area-wide control of *Aedes aegypti* in southern Puerto Rico

3 sticky, autocidal gravid ovitraps (AGO traps) per home reduced 80% the number of gravid females (traps were placed in 85% of homes)

Mosquito outbreaks were suppressed

Not clear if that level of reduction will prevent dengue outbreaks

Additional control measures would be needed to eliminate *Ae. aegypti* (Barrera et al. in preparation)
Spatial patterns of mosquito abundance

Vector control – AGO traps

No control traps

La Margarita
BG and AGO Trap Data

Legend
BG Data 8/15/2012
Average Aedes aegypti Females (trap/day)
- 0.00
- 0.01 - 0.50
- 0.51 - 1.00
- 1.01 - 1.50
- 1.51 - 2.00
- 2.01 - 3.00
- 3.01 - 12.00

AGO Data 8/15/2012
Average Aedes aegypti Females (trap/day)
- 0.00
- 0.01 - 0.50
- 0.51 - 1.00
- 1.01 - 1.50
- 1.51 - 2.00
- 2.01 - 3.00
- 3.01 - 12.00

Villodas
Release of Insects carrying a Dominant Lethal gene (RIDL) – Genetically Modified mosquitoes (transgenic)

- Released males would mate with wild females and all progeny would inherit the lethal gene and consequently die (unfortunately, some females are also released...)
- *Aedes aegypti* OX513A carries a lethal gene system so that larvae would die in the absence of tetracycline
- *Aedes aegypti* OX3604C is a female-flightless RIDL strain. When mosquitoes are reared without the antidote, tetracycline, adult females cannot fly or mate. Flightless females in the wild cannot seek hosts or mates, find a blood meal or spread disease.
- Also carry a gene that makes larvae fluorescent, so specimens can be distinguished (modified vs. wild)
- RIDL is under field evaluation (Brazil)
Using *Wolbachia* endosymbionts as a biological control

- **Population replacement** — replace wild population with infected *Wolbachia* mosquitoes that cannot transmit dengue viruses – being tested in Australia, Indonesia, Vietnam – Release males and females (Hoffman et al. 2011)

- **Population suppression**
  - Life-shortening *Wolbachia* - 50% reduction in adult lifespan – not being used
  - *Wolbachia*-induced cytoplasmic incompatibility (CI) – Release infected males that mate with wild females and have no offspring (O’Connor et al. 2012)
Conclusions

• New tools to monitor adult populations of *Ae. aegypti* will help to understand how different control approaches truly impact dengue vector populations

• It is unlikely that a single vector control tool will prevent dengue virus transmission or effectively control the vector population

• Populations of *Ae. aegypti* tend to recover quickly after disturbances – so control measures need to be sustained

• New approaches to controlling adult *Ae. aegypti* are promising if they can be integrated

• Preemptive vector control in areas known to be dengue hot spots and at appropriate times has the potential to reduce the burden of dengue (needs testing)
Thanks

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The findings and conclusions in this report are those of the author and do not necessarily represent the official position of the Centers for Disease Control and Prevention.
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