Thoughts on Integrated Mosquito Management

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University of California, Davis
Integrated Mosquito Management

Day of the Year

HUMAN CASES

DETECTION

CONTROL

AMPLIFICATION

Reactive emergency intervention

Personal Protection

Proactive vector management

Preventive methods
Integrated Vector Management

WHO:

“IVM is a rational decision-making process for the optimal use of resources for vector control. The approach seeks to improve the efficacy, cost-effectiveness, ecological soundness and sustainability of disease-vector control.”
WHO: Global Strategic Framework for IVM

• **Advocacy, social mobilization, regulatory control** for public health and empowerment of communities.

• **Collaboration within the health sector and with other sectors** through the optimal use of resources, planning, monitoring and decision-making.

• **Integration of non-chemical and chemical vector control methods**, and integration with other disease control measures.

• **Evidence-based decision making** guided by operational research and entomological and epidemiological surveillance and evaluation.

• **Development of adequate human resources, training and career structures** at national and local level to promote capacity building and manage IVM programs.
Transmission Theory for Mosquitoborne Pathogens

Mosquito-borne viruses with humans as amplifying hosts (e.g., dengue, Zika)
Mosquito-borne zoonoses (e.g., WNV)
What do you want to know?
Entomological Inoculation Rate

• Rate at which a person is bitten by infectious vectors per day

\[ EIR = m \alpha \phi \theta \]

• Depends on
  – \( m = \text{mosquitoes} / \text{person} \) = how many vectors are “out there” (expressed per person)
  – \( \alpha = \text{bites} / \text{day} \) = how often each vector bites
  – \( \phi = \text{human bites} / \text{all bites} \) = proportion of the bites on humans
  – \( \theta = \text{transmitting vectors} / \text{all vectors} \) = proportion of vectors that are infectious (infected and ready to transmit)
But we can’t directly measure the inoculation rate...

<table>
<thead>
<tr>
<th>EIR component (ideal)</th>
<th>Data (what we know)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(m) Ratio of mosquitoes to humans</td>
<td>Mosquito counts from traps</td>
</tr>
<tr>
<td>(a) Mosquito biting rate</td>
<td>Can be estimated as a function of temperature</td>
</tr>
<tr>
<td>(\phi) Proportion of mosquito bites on humans</td>
<td>Varies seasonally, and can be informed by several studies on host selection</td>
</tr>
<tr>
<td>(\theta) Proportion of mosquitoes that are infectious</td>
<td>Proportion of mosquitoes that are infected, determined through testing of female mosquitoes pooled in batches of ≤ 50</td>
</tr>
</tbody>
</table>
Surveillance for Human Disease

- Human disease cases
  - Active vs. passive detection
  - Usually the most important outcome (to us)
  - In some areas, the only available data
  - First indication of a problem for new introductions
Why can’t we just monitor disease cases for zoonotic pathogens like WNV?

- **Need to monitor enzootic cycles** in mosquitoes and birds to viral amplification before reaching high risk for humans or horses.
- **Reporting delays** for human and equine disease cases typically make the reports too late to guide control efforts.
- **“Noisy” spatial distribution** due to small numbers of disease cases (low incidence) that might not reflect actual risk.
- **Variation in exposure and vulnerability** of at-risk populations make them a spatially variable and insensitive indicator of risk.
Surveillance: Mosquitoes

- **Abundance**
  - Many ways to measure
    - Trapping
    - Active sampling
  - Different life stages of the vector
    - Mosquitoes: eggs, larvae, pupae, adults
  - Useful for evaluating control
  - Must establish baselines to compare across time and space

http://www.ncmvca.org/
Surveillance: Mosquitoes

- **WNV Infection Prevalence**
  - Trap live mosquitoes weekly
  - Identify to species
  - Test by RT-PCR in groups of 1-50
  - Estimate infection prevalence
Surveillance: Vertebrate Testing

• Infection in hosts (Dead Birds)
  – Less useful for viruses in live birds (short viremia)
  – Sometimes eval. for subset of pop. e.g., dead birds

• Serological testing (Sentinel Chickens)
  – Chickens tested every 2 weeks
  – % seroconverting provides a measure of transmission intensity
  – A few agencies also monitor seroprevalence in humans, wildlife

http://www.wuvcdo.org
Benefits and Costs of Vector Management

**Benefits**
- Reduction in disease
- Reduction in pests
- Improved quality of life, reduced economic burden

**Costs**
- Financial
- Human resources
- Human exposure to insecticides
- Non-target impacts
- Insecticide resistance
IVM best practices: data management

• Standardized record-keeping at the local level that ensures utility across spatial scales

• Data should be useful for
  1. Defining the problem (e.g., infection risk)
     • Extent
     • Intensity
  2. Measuring effects of interventions
Field data entry

Laboratory data entry

National Databases

Interactive Maps and Tools

Arbovirus bulletins, Automated emails

MosquitoNET

California Vectorborne Disease Surveillance Gateway

DART

DAVIS ARBOVIRUS RESEARCH & TRAINING

In the interactive maps and tools, certain dates, such as 4-Jan, 11-Jan, 18-Jan, 4-Jul, 11-Jul, and 18-Jul, are highlighted, indicating specific periods of interest.
### Mosquito Control: Data Entry

#### Update Collection

- **Collection ID:** 5674
- **Trap Type:** CO2
- **Collection Date:** 2015-08-25
  - Trap started the evening of 2015-08-24.
- **# of Traps:** 2
- **# of Nights/Trap:** 1
- **Trap(s) at Site:** 243032 - 242-Core Rd

**Identification Info:**

- **Latitude:** 38.357533
- **Longitude:** -121.44697

**Identification Notes:**
- If the Latitude is in the southern hemisphere, the value must be prefixed by the minus ‘-’ sign.
- If the Longitude is in the western hemisphere, the value must be prefixed by the minus ‘-’ sign.

**Comments:**

**Count of Species**

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<th>Species</th>
<th>M</th>
<th>F - Mixed</th>
<th>M - Unfed</th>
<th>F - Bloodfed</th>
<th>M - Gravid</th>
<th>Σ F</th>
<th>Unknown Sex</th>
<th>Eggs</th>
<th>Larvae</th>
<th>Pupae</th>
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#### Last Collection #1

- **Collection #1:** 5704
- **Trap Type:** GRVD
- **Trap at Site:** 213009
- **Collection Date:** 2015-08-25
- **# of Trap Nights:** 1
- **Identified By:**
- **Trap Problems:** No
- **Add Date:** 2015-08-25 01:54 PM

#### Other Collections

- **Last Collection #2**
- **Last Collection #3**
- **Last Collection #4**
- **Last Collection #5**

#### Open 2015 Pool #s

- **Used 2015 Pool #s**
- **Open 2015 Pool #s**
  - **4485 - 150000**
### California Mosquito-borne Virus Surveillance and Response Plan

<table>
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<tr>
<th>Risk Level</th>
<th>Avg. Daily Temperature</th>
<th>Adult mosquito abundance</th>
<th>Mosquito MIR/1,000</th>
<th>Chicken Seroconversions</th>
<th>Dead Bird Infections</th>
<th>Human Cases</th>
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<tr>
<td>1</td>
<td>&lt;56ºF</td>
<td>&lt; 50% 5-yr. Avg.</td>
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<td>0 in region</td>
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<td>50-90% 5-yr. Avg.</td>
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<td>≥ 1 in region, 0 in agency</td>
<td>≥ 1 in region, 0 in agency</td>
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<td>66-72ºF</td>
<td>91-150% 5-yr. Avg.</td>
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<td>1 flock in agency</td>
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<td>151-300% 5-yr. Avg.</td>
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<td>2 flocks in agency</td>
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<td>5</td>
<td>&gt;79ºF</td>
<td>&gt; 300% 5-yr. Avg.</td>
<td>&gt; 5.0</td>
<td>&gt;2 flocks in agency</td>
<td>&gt;5 in agency</td>
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<table>
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<th>SCORE</th>
<th>RISK LEVEL</th>
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<td>Normal season</td>
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<td>2.6—4.0</td>
<td>Emergency planning</td>
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<td>4.1—5.0</td>
<td>Epidemic</td>
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On the web at [http://westnile.ca.gov/resources.php](http://westnile.ca.gov/resources.php)
### CalSurv Gateway Risk Calculator

**Time Interval**: 2013 by Week

**Agency**: Sacramento-Yolo MVCD

**Spatial Filter**: City of Davis

**Target**: WNV

**Trap Type**: CO₂-baited traps, gravid traps

**Sex**: Female mosquitoes

**Species**: *Culex tarsalis, Culex pipiens*

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<th>Seroconversion</th>
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Note: Risk values range from 1 to 4, with 4 being the highest risk.
• Official state reporting mechanism
• Rapid reporting
  – Immediate reporting of test results to source agency via email
  – Immediate updates to databases & maps
• “Value Added”: tools for data analysis and visualization
• Agencies retain ownership of data
• User-level permissions and passwords
• Data export, including web services
• New tools for tracking pesticide applications & resistance testing
Capacity Building: Challenges

• Limited positions, low salaries, lack of appreciation of the field to make the field attractive as a career option
• Lack of “general”/organismal public health entomology faculty
• Funding of basic/molecular over applied/field research
  – Limited funding for research on vector control
• Public opinion and politics over sound science/lack of appreciation of VBDs by elected officials and public
Capacity Building

• Infrastructure
  – Dedicated funding stream for vectors/VBDs
  – Fee structure to support local vector management
  – Education of elected officials
  – Education of public health administrators
  – Communication: websites, public-facing data, social media, citizen science

• Career tracks
  – Standards for education and certification programs
  – Continuing education
  – Adequate pay scales
  – Internship opportunities
CDC Regional Centers of Excellence in VBDs
Pacific Southwest Center of Excellence in Vector-Borne Diseases

Knowledge & Capacity to Respond to Vector-Borne Diseases in the U.S.

**Research**
- Field vs. lab insect: resistance
- Sustainable use of insecticides
- Next-Gen Surveillance
  - Improved surveillance
  - New traps & diagnostics
- Innovative Control + Evaluation
  - Novel larvicides
  - Genetic control strategies
  - Optimizing release-based strategies
- Epidemiology & Vector Ecology
  - Improved estimates of vector abundance & control efficacy
  - Defining targets for intervention

**Training**
- Undergraduate,
  - Predoctoral,
  - Postdoctoral
- Professional
- Continuing Education
  - Vector control
  - Medical professionals
  - Public health agencies
- Student Research Grants
  - Support supplies & travel for predoc trainees in Region 9
  - Foster innovation & collaboration

**Collaboration**
- Community of Practice
  - University of California
  - California Dept. of Public Health
  - Mosquito & Vector Control Assoc. of California
- Collaborative Workshops
  - Open to public health and vector control in Region 9
  - Emphasize core competencies in entomology & insecticide resistance monitoring

**Services**
- Diagnostic Test Development
- New Technologies Translation
- Vector Genetics
- Data Management & Analytics

**Diverse Interdisciplinary Team**
- Entomology, Ecology, Epidemiology,
- Veterinary Medicine, Engineering,
- Human Medicine, Public Health,
- Vector Control

**Study Area (California & Region 9)**
- Large, diverse human population
- Diverse ecological zones & vector-borne disease threats
- Long-standing working relationships
Pacific Southwest Center of Excellence in Vector-Borne Diseases

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