Impact of environmental change on the transmission of arboviruses

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content

• Background – what are arboviruses
• Surveillance and PHL testing
• Intervention response to surveillance data
• Impact of environmental change
  – Population growth and urbanization
  – Effects of warming temperature
  – Thoughts on rainfall
Background

• Arboviruses
  – Taxonomically diverse group of viruses transmitted by arthropods
  – Most originated as tropical zoonoses, some of which evolved to become anthroponoses [e.g., Yellow fever virus]

• Anthropogenic impacts:
  ➢ Human population growth
  ➢ Landscape change
  ➢ Connectivity [transportation]
  ➢ Climate change
Our NA problem: West Nile virus

- **Taxonomy:** Flavivirus in the Japanese encephalitis serogroup. Related to SLEV, JEV
- **Discovery:** Isolated during a fever survey in the West Nile district of Uganda in 1937
- **Disease:** ranges from inapparent infection to flu-like illness to neuroinvasive disease to death. Possible chronic kidney infarction.
- **Epidemics:** Upper Egypt and South Africa in 1950s, Mediterranean and eastern Europe in 1990s, New World in 2000s – remarkable spread in the New World: east to west coast and from Canada to Argentina in 5 years
- **No vaccine for humans**

In USA: >30,000 confirmed cases
> 2M infections
2012 resurgence with 5,670 cases
What can be done?
Points of WNV intervention

Integrated vector management

Emergency adulticiding

Reservoir removal or Vaccination??

Personal protection:
- avoidance
- repellents

Vaccination

Modified from CDC website
INTEGRATED VECTOR MANAGEMENT: RESPONSE PARADIGM

Need decision support to decide what to do when

Reactive emergency intervention

PUBLIC EDUCATION: Personal Protection

Vector population management

Preventive methods

Control window
Tracking WNV

Climate variation:
1. Only early season predictor
2. Determines, in part, the shape of the amplification curve
Mosquito Sampling: Abundance

- **NJ light trap**
- **Dry ice-baited trap**
- **Gravid female trap**

Mosquitoes sorted to species and counted

*Culex* vectors carefully counted into pools of 50
Enzootic Transmission Measures

1. Free ranging bird serology [not universally done]

2. Sentinel chicken serology

3. Dead bird reports and testing

Paper strips rapidly tested by EIA and confirmed by IFA or western blot
Molecular diagnostics: real time RT-PCR

Mixer mill

ABI MagMax RNA Extraction unit

TaqMan real time RT-PCR unit ABI Vii7A

TaqMan screen output
CalSurv Surveillance Gateway
Rapid Arbovirus Data Acquisition and Reporting system

MVCAC agencies enter field data & have access for in-house reports

TOPS data

Field data retrieved and laboratory test results entered

Central server

Results automatically sent to CDC

Historical Database updated

CDPH Arbovirus bulletins

Interactive maps automatically updated

Results reported to client automatically by email after entry

Risk Estimates
CLIMATE EFFECTS ALL COMPONENTS OF TRANSMISSION CYCLES

VIRUS

VECTOR

CLIMATE

HOST
VECTORIAL CAPACITY
[Factors affected by temperature]

\[ C = ma^2 P^n V/ \log_e P \]

\( C \) = cases per case per day
\( ma \) = host biting rate
\( a \) = HI/GC, where HI = host selection index, and GC = duration of the gonotrophic cycle
\( P \) = Probability of daily survival
\( n \) = Duration of the extrinsic incubation period
\( V \) = vector competence

Effects of temperature on mosquito life cycle

Aquatic stages

Terrestrial stages

Larval development

Gonotrophic cycle

Threshold = 6.2°C
DD = 274

Threshold = 5°C
DD = 33
Effects of host viremia and temperature on WNV infection and transmission

A. INFECTION

Percent infected vs. Host titer

B. WNV GROWTH

Body titer vs. Days post infection

C. EIP$_{50}$

Transmitting [%] vs. Days post infection

D. TRANSMISSION

EIP [Days] vs. Temperature [°C]

Reisen et al. 2006. JME 43:309
How is temperature related to WNV transmission?

- **Gonotrophic Cycle**
  - Length shortens with ↑ temperature
  - Affects rate of population growth & frequency of contact between mosquitoes and hosts

- **Extrinsic Incubation Period**
  - Time from mosquito infection → potential transmission

- For WNV, EIP declines at faster rate than GC with ↑ temperature, so interplay affects transmission

- BT [bites per transmission] = GC/EIP

Reisen et al 1992 *JME*
Reisen et al 2006 *JME*
Dynamics of West Nile virus, Kern Co, 2004
Transmission: Temp >25°C, EIP<10d, BT = 2

Reisen et al. 2006. JME 43:309
BT = EIP/GC or bites required for transmission during WNV introduction, 2004
National Cumulative 2007 Human Disease Cases: 3630

National Cumulative 2008 Human Disease Cases: 1356
WNV Cases in Canada

**2003**

**2007**

**2008**

Regina, SK

Map showing cases of WNV (West Nile Virus) in Canada for the years 2003, 2007, and 2008. The map highlights the number of cases in various provinces and territories. The graph on the right shows temperature variations over time in Regina, SK.
BT = EIP/GC (# bites for transmission) with 50 y climate change

- Greatest 50 y impact is expected in SF Bay Area, coastal southern CA where human population densities are high

- Little change in the warmest areas of the state
Climate anomalies and WNV cases for 2012

Cases as of 25 Sep 12: Texas epicenter = 1,355
National wide = 3,539 [Kansas = 30]
Variable effects of water
Too much vs Too little

• Floods:
  – Reduces edge effect
  – Washout larvae
  – Scour waste water systems

• Drought:
  – Dries wetlands
  – Channels riparian systems
  – Increases irrigation: urban curb drizzle increases waste water system production.
Variable Effects of Rainfall: 
*Culex tarsalis* abundance at 282 sites from 1950 to 2000. 
C. Abundance during spring vs rain during winter.  
D. Abundance during summer vs rain during spring.  

*Culex tarsalis* abundance from 1950 to 2000 during A) spring and B) summer vs. 1 Apr snow water equivalents at Donner summit.
ANTHROPOGENIC FACTORS: ADJUSTABLE RATE MORTGAGES AND HOUSING MARKET DECLINE

Notice of sale [NOS] and notice of delinquency rates in Kern County by quarter [Q] accompanied a 300% increase in human cases [57 in 2006 to 177 in 2007]

Reisen et al. 2008. EID 14: 1747
Adjustable rate mortgages → Abandoned houses → Neglected swimming pools

Bakersfield, 2007

7/42 positive 59% tarsalis

Reisen et al. 2008. EID
Google Earth View of Dallas, TX, 31 Mar 11
Summary

• WNV is now endemic to NA
• 2012 showed WNV has the ability for widespread resurgence whenever conditions are conducive for amplification
• Effective mosquito control directed by surveillance science currently is the only public health intervention
• Warming will increase 1) the geographic distribution of the virus, 2) the length of the transmission season, and 3) the rate of virus amplification facilitating outbreaks
• Timely enzootic surveillance and human diagnostics will be necessary for risk recognition and timely intervention
• WNV will not be the last arbovirus to invade the USA; likely suspects include CHIKV, JEV and RRV from Asia, RVFV from Africa, SINDV from Europe, DENV and others from the Neotropics. Therefore, a vigilant diagnostic laboratory must not only provide rapid data for decision support, but also be able to detect new problems before they become established.