GIS
&
Vector Borne Diseases

Thomas Talbot
March 5, 2013
Deaths from vector-borne disease

VBD Deaths/million

- 0 - 1
- 1 - 20
- 20 - 50
- 50 - 200
- 200 - 500
- 500 - 1900
- No Data

The boundaries shown on this map do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted lines on maps represent approximate border lines for which there may not yet be full agreement.
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<table>
<thead>
<tr>
<th>Indicator</th>
<th>Value (year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life expectancy at birth (years) males</td>
<td>50.0 (2005)</td>
</tr>
<tr>
<td>Life expectancy at birth (years) females</td>
<td>51.0 (2005)</td>
</tr>
<tr>
<td>Healthy life expectancy (HALE) at birth (years) males</td>
<td>41.0 (2002)</td>
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<tr>
<td>Healthy life expectancy (HALE) at birth (years) females</td>
<td>42.0 (2002)</td>
</tr>
<tr>
<td>Probability of dying (per 1,000 population) between 15 and 60 years (adult mortality rate) males</td>
<td>444 (2005)</td>
</tr>
<tr>
<td>Probability of dying (per 1,000 population) between 15 and 60 years (adult mortality rate) females</td>
<td>434 (2005)</td>
</tr>
<tr>
<td>Infant mortality rate (per 1,000 live births)</td>
<td>87.0 (2005)</td>
</tr>
<tr>
<td>Neonatal mortality rate (per 1,000 live births)</td>
<td>30 (2004)</td>
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<tr>
<td>Maternal mortality ratio (per 100,000 live births)</td>
<td>730 (2000)</td>
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<tr>
<td>Deaths due to HIV/AIDS (per 100,000 population per year)</td>
<td>282 (2005)</td>
</tr>
<tr>
<td>Deaths due to tuberculosis among HIV-negative people (per 100,000 population)</td>
<td>14.8 (2005)</td>
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<tr>
<td>Deaths due to tuberculosis among HIV-positive people (per 100,000 population)</td>
<td>8 (2005)</td>
</tr>
<tr>
<td>Age-standardized mortality rate for non-communicable diseases (per 100,000 population)</td>
<td>848.0 (2002)</td>
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<tr>
<td>Age-standardized mortality rate for cardiovascular diseases (per 100,000 population)</td>
<td>436.0 (2002)</td>
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<td>Age-standardized mortality rate for cancer (per 100,000 population)</td>
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<td>Age-standardized mortality rate for injuries (per 100,000 population)</td>
<td>118.0 (2002)</td>
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<td>Years of life lost to communicable diseases (%)</td>
<td>81.0 (2002)</td>
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<tr>
<td>Years of life lost to non-communicable diseases (%)</td>
<td>11.0 (2002)</td>
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<tr>
<td>Years of life lost to injuries (%)</td>
<td>8.0 (2002)</td>
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<tr>
<td>Deaths among children under five years of age due to neonatal causes (%)</td>
<td>24.8 (2000)</td>
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<tr>
<td>Deaths among children under five years of age due to HIV/AIDS (%)</td>
<td>7.2 (2000)</td>
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<td>Deaths among children under five years of age due to diarrhoeal diseases (%)</td>
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<td>Deaths among children under five years of age due to measles (%)</td>
<td>4.1 (2000)</td>
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<td>Deaths among children under five years of age due to malaria (%)</td>
<td>22.8 (2000)</td>
</tr>
<tr>
<td>Deaths among children under five years of age due to injuries (%)</td>
<td>2.2 (2000)</td>
</tr>
</tbody>
</table>
Definitions

• A **vector** is an organism that does not cause disease itself but which transmits infection by conveying pathogens from one host to another.

• An **intermediate host** is an organism inside which a parasite does not sexually reproduce.

• The **definitive host** is the host in which the parasite reproduces sexually.
Risk of human infection greatest in late spring and summer.
Definitions

- **Amplifying hosts**, developing sufficient level of infection to transmit the infection to vectors which go on to infect other vectors.

- **Dead-end hosts** the disease does not multiply as readily and vectors do not get infected from host. In humans, West Nile Virus, Swimmers Itch.
Insect Vectors

- **Anopheles gambiae** (Malaria)
- **Ixodes scapularis** (Lyme Disease)
- **Simulium damnosum** (River Blindness)
- **Glossina morsitans** (Sleeping Sickness)
- **Phlebotomus dubosci** (Leshmaniasis)
<table>
<thead>
<tr>
<th>Vector</th>
<th>Disease</th>
<th>Pathogen Type</th>
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<tbody>
<tr>
<td>Mosquitoes</td>
<td>Filarialis</td>
<td>Helminth</td>
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<tr>
<td></td>
<td>Malaria</td>
<td>Protozoa</td>
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<tr>
<td></td>
<td>Dengue fever</td>
<td>Virus</td>
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<tr>
<td></td>
<td>Yellow fever</td>
<td>Virus</td>
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<tr>
<td></td>
<td>St. Louis encephalitis</td>
<td>Virus</td>
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<tr>
<td></td>
<td>Eastern equine encephalitis</td>
<td>Virus</td>
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<td></td>
<td>Western equine encephalitis</td>
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<td></td>
<td>West Nile</td>
<td>Virus</td>
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<td></td>
<td>Rift Valley fever</td>
<td>Virus</td>
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<tr>
<td>Ticks</td>
<td>Lyme disease</td>
<td>Bacteria</td>
</tr>
<tr>
<td></td>
<td>Rocky Mountain spotted fever</td>
<td>Bacteria</td>
</tr>
<tr>
<td></td>
<td>Q fever</td>
<td>Bacteria</td>
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<td></td>
<td>Tularemia</td>
<td>Bacteria</td>
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<td></td>
<td>Relapsing fever</td>
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<td></td>
<td>Ehrlichiosis</td>
<td>Bacteria</td>
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<td></td>
<td>Colorado tick fever</td>
<td>Virus</td>
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<tr>
<td></td>
<td>Crimean hemorrhagic fever</td>
<td>Virus</td>
</tr>
<tr>
<td></td>
<td>Babesiosis</td>
<td>Protozoa</td>
</tr>
<tr>
<td>Mites</td>
<td>Q fever</td>
<td>Bacteria</td>
</tr>
<tr>
<td>Deerflies</td>
<td>Rickettsioses/rickettsialpox</td>
<td>Bacteria</td>
</tr>
<tr>
<td>Tsetse flies</td>
<td>Tularemia</td>
<td>Bacteria</td>
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<tr>
<td></td>
<td>Sleeping sickness (African</td>
<td>Protozoa</td>
</tr>
<tr>
<td></td>
<td>trypanosomiasis)</td>
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<tr>
<td>Blackflies</td>
<td>Onchocerciasis</td>
<td>Helminth</td>
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<tr>
<td>Muscoid flies</td>
<td>Yaws</td>
<td>Bacteria</td>
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<td>Sandflies</td>
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<td>Protozoa</td>
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<td></td>
<td>Sandfly fever</td>
<td>Virus</td>
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<tr>
<td></td>
<td>Vesicular stomatitis</td>
<td>Virus</td>
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<tr>
<td>Lice</td>
<td>Epidemic typhus</td>
<td>Bacteria</td>
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<tr>
<td></td>
<td>Trench fever</td>
<td>Bacteria</td>
</tr>
<tr>
<td>Fleas</td>
<td>Endemic typhus</td>
<td>Bacteria</td>
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<td></td>
<td>Bubonic plague</td>
<td>Bacteria</td>
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<tr>
<td>Reduviids (also known as</td>
<td>Chagas disease (American</td>
<td>Protozoa</td>
</tr>
<tr>
<td>bed bugs, kissing bugs,</td>
<td>trypanosomiasis)</td>
<td></td>
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<tr>
<td>cone-nose bugs)</td>
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</table>
Schistosomiasis

Fig. 298-1. Life cycle of schistosomiasis.
Guinea Worm Eradication Efforts
Removing Guinea Worm
Guinea worm is more than 3,000 years old. It has been found in calcified Egyptian mummies. Many believe the symbol of medicine often interpreted as a snake wrapped around a stick, may be a Guinea worm.
Fighting in Mali Hampers Guinea Worm Disease Eradication

By DONALD G. McNEIL Jr.
Published: January 17, 2013

Fighting in Mali has damaged the global effort to eradicate Guinea worm disease, former President Jimmy Carter said Thursday.

Guinea worm, also known as dracunculiasis, and polio are the two diseases closest to total eradication; each is down to fewer than 1,000 known cases. But both eradication efforts have had repeated setbacks: in Pakistan, nine people administering polio vaccines were killed recently, presumably by the Taliban. In rebel-held areas of northern Mali, teams that remove worms and teach villagers how to protect their drinking water have been unable to operate since April, Ernesto Ruiz-Tiben, head of Guinea worm eradication for the Carter Center, said during a video news conference with Mr. Carter.

Mali had only seven of the world’s 542 confirmed cases in 2012, but three of them were detected in Niger among refugees from Mali, which suggests that the disease is spreading.
Variables used
Vector Borne Disease Mapping

- Temperature
- Humidity
- Rainfall
- Landcover
- Landuse
- Density of susceptible populations
  - Vectors
  - Hosts
- Altitude
- Water temperature & quality
- Vector breeding locations
Normalized Difference Vegetation Index (NDVI)

Numerical indicator used to analyze remote sensing measurements to assess whether the target being observed contains live green vegetation or not.

Plants reflect near-infrared (NIR) light since it is not used in photosynthesis. Visible red light is absorbed.

\[
NDVI = \frac{(NIR - RED)}{(NIR + RED)}
\]
Protective Barriers & Public Health Measures

- Clean water
- Sanitation
- Mosquito screens (bed nets)
- Clothing
- Change human behavior
- Insect repellants
- Change the environmental habitats
- Vector Control (pesticides)
- Control of pathogen in the hosts
  - Vaccines
  - Antibiotics
• Distance between the vectors & hosts.

• Physical barriers between the host & vector.
Malaria Risk model shows the suitability of potential distribution of malaria in the average year.

- Based on long term climate data
- Not based on actual malaria data
- 5km grid
Malaria in sub-Saharan Africa accounted for between 700,000 and 900,000 deaths in children under 5.

CDC & WHO 2005

90% of malaria deaths occur in Africa. 300-500 million clinical cases/yr

WHO 1995

Compare this with 124 West Nile Virus deaths and 3,600 clinical cases of in US for 2007. CDC
Definitions

• Where climate is unsuitable malaria is either absent or may occur as epidemics.

• **Endemic** = malaria occurs yearly. Can be seasonal

• **Epidemic** = distinct differences from year to year. Some years malaria is absent.
Definitions

- Holo-endemic >75%
- Hyper-endemic 51-75%
- Meso-endemic 11-50%
- Hypo-endemic <10%

- Prevalence can be measured through blood tests in children.
Temperature is one factor that determines whether the vector of malaria can live long enough to transmit disease.
Madagascar
Cameroon Population
Species of vector impacts the effectiveness of control strategies

Chloroquine Failure Rates in Côte d'Ivoire, 1997 - 2001

Failure rates (%)
- Acr: adequate clinical and parasitological response
- Lpf: late parasitological failure
- Lcf: late clinical failure
- Etf: early treatment failure
- Cf: clinical failure
- Tf: total failure rate

Pies representing proportionally the number of patients

Population density (pers./sq.Km)
- 0 - 10
- 10 - 50
- 50 - 100
- 100 - 250
- 250 - 500
- 500 - 750
- 750 and more

Data Source: Ministry of Health/Published articles
Map Production: Public Health Mapping & GIS
Communicable Diseases (CDS)
World Health Organization
© WHO June 2004. All rights reserved.
Figure 2. Supervised maximum likelihood classification map (combined NDVI image, the texture bands, and the four spectral bands). Classification of land cover within a village radius of 2 km with 11 colours indicating different land cover classes. All classes describing the crops banana/plantain, cacao, palm trees producing palm oil fruits, and oranges were mainly mixed fields but dominated by one of these crops. Swampy areas were characterized by either the presence of a river or stream nearby or an agricultural crop cultivated in the vicinity. Water was characterized by a river, stream or lake. Deforested areas were characterized by roads as well as burned, grassy or bushy underground or open spaces. Forest referred to areas with dense tree cover, mostly with a closed canopy.

doi:10.1371/journal.pone.0017905.c002
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<th>Determinant</th>
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<th>95% Confidence Interval</th>
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<td>Population density</td>
<td>0.87</td>
<td>0.70–1.07</td>
<td>0.176</td>
</tr>
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<td>Built-up areas (houses)</td>
<td>2.24</td>
<td>1.54–3.24</td>
<td>&lt;0.001</td>
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<td>Deforested area and roads</td>
<td>1.00</td>
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<td>0.988</td>
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<td>Forest</td>
<td>0.53</td>
<td>0.28–0.99</td>
<td>0.029</td>
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Clark AB, RP, 1964, Collecting Mosquito Larvae From Banana Axils (Major Frank Dowell, Chief of Entomology)
Pineapple and plantain/banana plantations should be isolated from living quarters. This is because the axils of these plants when filled with rainwater support the breeding of various mosquito species.

Modelling the potential transmission Dengue with climate change

Areas infested with *Aedes aegypti*

Areas with *Aedes aegypti* and recent epidemic dengue

**World Distribution of Dengue (1990s)**

- **Areas infested with *Aedes aegypti***
- **Areas with *Aedes aegypti* and recent epidemic dengue**
Model selection

• Logistic regression used to model the presence or absence of dengue.

• Explanatory variables: temperature, rainfall, humidity, singly or in combination

• Cross validation: compared observed values with predictions from a model.
Model fitting: baseline

• The model was fitted using the original gridded climate data

  ➢ Modeled baseline risk of dengue transmission each 0.5 degree grid cell, on the basis of observed 1961-1990 climate.
  ➢ Model accuracy assessed by comparing the results with the known distribution of dengue fever.
Results

- Vapour pressure was found to be the single best climatic predictor of dengue transmission.
- When areas at risk of dengue were defined by a cut-off probability of 0.5, the model classified 89% of the grid cells accurately.
Future risk

- Regression model to estimate risk of transmission potential in a future world, based on global change model projections of climate
Model of baseline transmission potential (1961-1990 climate)
Model of future transmission potential (2080s climate)
Habitat classification of Mendocino County based on Landsat TM5 imagery. Habitats with primary risk of exposure to *Ixodes pacificus* nymphs (woodlands with leaf or fir needle litter) are shown in green, those with primary risk of exposure to *I. pacificus* adults (chaparral, grass, woodland with grass) are shown in yellow, and habitats with minimal or no risk of exposure to ticks (agricultural, barren, urban or water) are shown in blue.
Figure 2. Supervised maximum likelihood classification map (combined NDVI image, the texture bands, and the four spectral bands). Classification of land cover within a village radius of 2 km with 11 colours indicating different land cover classes. All classes describing the crops banana/plantain, cacao, palm trees producing palm oil fruits, and oranges were mainly mixed fields but dominated by one of these crops. Swampy areas were characterized by either the presence of a river or stream nearby or an agricultural crop cultivated in the vicinity. Water was characterized by a river, stream or lake. Deforested areas were characterized by roads as well as burned, grassy or bushy underground or open spaces. Forest referred to areas with dense tree cover, mostly with a closed canopy.
Table 4. Influence of determinants on malaria incidence.

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Life Cycle of *Onchocerca volvulus*:

**Blackfly Stages**

1. Blackfly (genus *Simulium*) takes a blood meal (L3 larvae enter bite wound)

2. Subcutaneous tissues

3. Adults in subcutaneous nodule

4. Adults produce unsheathed microfilariae that typically are found in skin and in lymphatics of connective tissues, but also occasionally in peripheral blood, urine, and sputum.

5. Blackfly takes a blood meal (ingests microfilariae)

6. Microfilariae penetrate blackfly's midgut and migrate to thoracic muscles

7. L1 larvae

8. L3 larvae

9. Migrate to head and blackfly's proboscis

**Human Stages**

- Infective Stage
- Diagnostic Stage

[Image credit: CDC, http://www.dpd.cdc.gov/dpdx]
River Blindness in Africa
Ivermectin is an inexpensive and effective drug to treat River Blindness. The drug can have serious side effects including death in patients who are also infected with Loa Loa.

A model of the presence or absence of L loa in surveyed individuals was created by use of logistic regression with digital environmental data (forest, land cover, rainfall, temperature, topography, soil) as predictor variables.

MC Thomson et al. Lancet 2000
Ivormectin is an inexpensive drug to treat River Blindness, it can have serious side effects in patients who are also infected with Loa Loa.

A model of the presence or absence of *L. loa* in surveyed individuals was created by use of logistic regression with digital environmental data (forest, landcover, rainfall, temperature, topography, soil) as predictor variables.
Bloomberg Donating $100M to Help Fight Polio

By THE ASSOCIATED PRESS
Published: February 28, 2013 at 12:27 AM ET

SEATTLE (AP) — New York Mayor Michael Bloomberg has pledged $100 million to help the Bill & Melinda Gates Foundation and others to fight polio around the world.

The Seattle-based Gates Foundation said Bloomberg was set to announce the donation to the Global Polio Eradication Initiative on Thursday. That organization has a six-year plan to eliminate polio.

Polio is a vaccine-preventable disease that has been eradicated in most countries, but it still causes paralysis or death in some parts of the world, including Nigeria, Pakistan and Afghanistan. India was declared polio free in early 2012.

Fewer than 225 people had polio in 2012, the Gates Foundation said.
Polio endemic countries

- Some exportations
- Polio endemic countries
Tracking the polio virus down the Congo River: a case study on the use of Google Earth in public health planning and mapping by Raoul Kamadjeu - GIS & Public Health Day 2009, Albany NY
Another view of the river

Zooming on the Congo River

Altitude: 1000 m
Another closer view of the Congo

Populated islands
Population living within $\frac{1}{2}$ mile of wetlands

Census Blocks: 1,180
Total Population: 85,559
Population 65+ years: 10,753
WNV Positive Bird:
- American Crow
- Blue Jay
- Fish Crow
- Other species

WNV Positive Ill / Dead Birds
February 11
1 Bird
WNV Positive Bird:
- American Crow
- Blue Jay
- Fish Crow
- Other species

WNV Positive Ill / Dead Birds
April 7
2 Birds
WNV Positive Bird:
- American Crow
- Blue Jay
- Fish Crow
- Other species

WNV Positive Ill / Dead Birds
May 26
4 Birds
WNV Positive Bird:
- American Crow
- Blue Jay
- Fish Crow
- Other species

WNV Positive Ill / Dead Birds
June 16
6 Birds
WNV Positive Bird:
- American Crow
- Blue Jay
- Fish Crow
- Other species

WNV Positive Ill / Dead Birds
June 23
9 Birds
WNV Positive Bird:
- American Crow
- Blue Jay
- Fish Crow
- Other species

WNV Positive Ill / Dead Birds
June 30

19 Birds
WNV Positive Bird:
- American Crow
- Blue Jay
- Fish Crow
- Other species

WNV Positive Ill / Dead Birds
July 7
28 Birds
WNV Positive Bird:
- American Crow
- Blue Jay
- Fish Crow
- Other species

WNV Positive Ill / Dead Birds
July 14
57 Birds
WNV Positive Bird:
- American Crow
- Blue Jay
- Fish Crow
- Other species

WNV Positive Ill / Dead Birds
July 21
138 Birds
WNV Positive Bird:
- American Crow
- Blue Jay
- Fish Crow
- Other species

WNV Positive Ill / Dead Birds
July 28
238 Birds
WNV Positive Bird:
- American Crow
- Blue Jay
- Fish Crow
- Other species

WNV Positive Ill / Dead Birds
August 4
313 Birds
WNV Positive Bird:
- American Crow
- Blue Jay
- Fish Crow
- Other species

WNV Positive Ill / Dead Birds
August 18

506 Birds
WNV Positive Bird:
- American Crow
- Blue Jay
- Fish Crow
- Other species

WNV Positive Ill / Dead Birds
August 25
577 Birds
WNV Positive Bird:
- American Crow
- Blue Jay
- Fish Crow
- Other species

WNV Positive Ill / Dead Birds
September 1

674 Birds
WNV Positive Bird:
- American Crow
- Blue Jay
- Fish Crow
- Other species

WNV Positive Ill / Dead Birds
September 15
972 Birds
WNV Positive Bird:
- American Crow
- Blue Jay
- Fish Crow
- Other species

WNV Positive Ill / Dead Birds
September 22

1,089 Birds
WNV Positive Bird:
- American Crow
- Blue Jay
- Fish Crow
- Other species

WNV Positive Ill / Dead Birds
October 6

1,216 Birds
WNV Positive Bird:
- American Crow
- Blue Jay
- Fish Crow
- Other species

WNV Positive Ill / Dead Birds
October 13
1,242 Birds
WNV Positive Bird:
- American Crow
- Blue Jay
- Fish Crow
- Other species

WNV Positive Ill / Dead Birds
October 20

1,255 Birds

Less than 1% of positive dead birds are not shown on the map due to insufficient submission data. Data as of 10/20.
WNV Positive Bird:
- American Crow
- Blue Jay
- Fish Crow
- Other species

WNV Positive Ill / Dead Birds
October 27
1,259 Birds
WNV Positive Bird:
- American Crow
- Blue Jay
- Fish Crow
- Other species

WNV Positive Ill / Dead Birds
November 3
1,263 Birds