- A new resource for online mapping of mosquito, tick and sand fly species distribution data

Desmond Foley, Richard Wilkerson and Leopoldo Rueda

Division of Entomology, Walter Reed Army Institute of Research, 503 Robert Grant Avenue, Silver Spring MD 20910 USA.
WRBU, Smithsonian Institution, Washington DC USA
• A database of geo-referenced vector surveillance data, to increase understanding of the biogeography and ecology of vectors, and the distribution of vector-borne diseases
VectorMap.org

- Attributes
  - Includes all species: a biodiversity and vector-borne disease assessment tool
  - Museum based: emphasis on records backed by reliably identified voucher specimens
  - Geocoordinates: standardized terminology and methodology
  - Data use: freely available, full attribution of records
2009 MosquitoMap (ArcGIS 9.2 – 10)

2011 VectorMap (ArcGIS 10)

- Mosquito, tick and sand fly point data (~280k records)
- Vector distribution models
- Disease and host layers
- Host, parasite and ecology data
Mosquito Distribution Models

- Taxonomic data
- Point occurrence data
- Environmental data

Mosquito Distribution Models
Workflow of VectorMap

Collection points → Distribution models → VectorMap → Vector maps → MAC → Disease risk assessment
VectorMap point data

Spatial
e.g. ‘One-off’
data

Temporal
e.g. routine
weekly data

Vector

MosquitoMap

TickMap

SandflyMap

MiteMap

Host/Reservoir

HostMap

VectorSurv

Figure 4. Page 4 of 7
"Alaska, off the coast of California"
"possibly central Chile"
"between Los Angeles and San Francisco"
"Mexico to Argentina"
"Location 201"
"Bob Jones’ yard"
"Coast"
"Bridge E of Lodge"
"near Sand dunes"
"Ranch"
"National Park"
"Pacific Ocean somewhere toward Australia"
Mississippi river
Mmap Data schema follows Darwin Core Standards with the addition of fields specific for mosquitoes, e.g. parasite data, larval habitats, behavior.

(--The Darwin Core is a specification of data concepts and structure intended to support the retrieval and integration of primary data that documents the occurrence of organisms in space and time and the occurrence of organisms in biological collections)
MosquitoMap Search Page and Base Map
USER SCENARIOS

Point and distribution models:
• What species have been collected in an AOI
• Where has a certain species been collected
• Where is a certain species expected
• Where is rich in species
• How to contribute collection records
• How to download data

Mal-area Calculator:
• Compare AOI for relative risk of VBD
• Compare AOI for distribution of hazard
• Compare sites for Human settlement
What species have been collected in an AOI
Where has a certain species been collected
Where is a certain species expected
Where is rich in species
How to contribute collection records

Excel Mapper

Collection forms
## How to download data

### Excel

<table>
<thead>
<tr>
<th>ScientificName</th>
<th>SubmitID</th>
<th>SubmitOrg</th>
<th>SubmitName</th>
<th>SubmitPerm</th>
<th>SubmitPermM</th>
<th>SubmitPermF</th>
<th>SubmitPermT</th>
<th>SubmitAddDate</th>
<th>LastModDate</th>
<th>Collector</th>
<th>InstitutionCode</th>
<th>CollectionCode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anopheles sp.</td>
<td>12</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>12</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>12</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>12</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
</tr>
<tr>
<td>Anopheles sp.</td>
<td>20</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>20</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>20</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>20</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
</tr>
<tr>
<td>Anopheles sp.</td>
<td>45</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>45</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>45</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>45</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
</tr>
<tr>
<td>Anopheles sp.</td>
<td>53</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>53</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>53</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>53</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
</tr>
<tr>
<td>Anopheles sp.</td>
<td>69</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>69</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>69</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>69</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
</tr>
<tr>
<td>Anopheles sp.</td>
<td>75</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>75</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>75</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>75</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
</tr>
<tr>
<td>Anopheles sp.</td>
<td>77</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>77</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>77</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>77</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
</tr>
<tr>
<td>Anopheles sp.</td>
<td>78</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>78</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>78</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>78</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
</tr>
<tr>
<td>Anopheles sp.</td>
<td>82</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>82</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>82</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>82</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
</tr>
<tr>
<td>Anopheles sp.</td>
<td>84</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>84</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>84</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>84</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
</tr>
<tr>
<td>Anopheles sp.</td>
<td>123</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>123</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>123</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>123</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
</tr>
<tr>
<td>Anopheles sp.</td>
<td>129</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>129</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>129</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>129</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
</tr>
<tr>
<td>Anopheles sp.</td>
<td>186</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>186</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>186</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>186</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
</tr>
<tr>
<td>Anopheles sp.</td>
<td>219</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>219</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>219</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>219</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
</tr>
<tr>
<td>Anopheles sp.</td>
<td>223</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>223</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>223</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>223</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
</tr>
<tr>
<td>Anopheles sp.</td>
<td>225</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>225</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>225</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>225</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
</tr>
<tr>
<td>Anopheles sp.</td>
<td>237</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>237</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>237</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>237</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
</tr>
<tr>
<td>Anopheles sp.</td>
<td>240</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>240</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>240</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>240</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
</tr>
<tr>
<td>Anopheles sp.</td>
<td>241</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>241</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>241</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>241</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
</tr>
<tr>
<td>Anopheles sp.</td>
<td>242</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>242</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>242</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>242</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
</tr>
<tr>
<td>Anopheles sp.</td>
<td>244</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>244</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>244</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>244</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
</tr>
<tr>
<td>Anopheles sp.</td>
<td>246</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>246</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>246</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>246</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
</tr>
<tr>
<td>Anopheles sp.</td>
<td>247</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>247</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>247</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>247</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
</tr>
<tr>
<td>Anopheles sp.</td>
<td>249</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>249</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>249</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
<td>249</td>
<td>Walter Reed</td>
<td><a href="http://www.w.foley/dh">http://www.w.foley/dh</a></td>
</tr>
</tbody>
</table>

### Google Earth

- **Anopheles braziliensis**
- **Culex quinquefasciatus**
- **Culex molestus**
- **Culex sp.**

[Map Image]
USER SCENARIOS

*Point and distribution models:*
- What species have been collected in an AOI
- Where has a certain species been collected
- Where is a certain species expected
- Where is rich in species
- How to contribute collection records
- How to download data

*Mal-area Calculator:*
- Compare AOI for relative risk of VBD
- Compare AOI for distribution of hazard
- Compare sites for Disease and Human settlement
Mal-area Calculator – quantifying the Mal-area or area of co-occurrence (VPH) for Human (H), Parasite (P) and Vector (V)
Compare AOI for relative risk of VBD
Compare AOI for distribution of hazard

### Area of Interest

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum positive pixel value</td>
<td>1</td>
</tr>
<tr>
<td>Minimum positive pixel value</td>
<td>0.1</td>
</tr>
<tr>
<td>Sum of pixel values</td>
<td>6,946.4</td>
</tr>
<tr>
<td>Average pixel value</td>
<td>0.5</td>
</tr>
<tr>
<td>Average positive pixel value</td>
<td>0.91</td>
</tr>
<tr>
<td>Area of interest (number of pixels)</td>
<td>14,431</td>
</tr>
<tr>
<td>Area of Mal-area (number of positive pixels)</td>
<td>7,637</td>
</tr>
<tr>
<td>Area of interest covered by Mal-area</td>
<td>52.92%</td>
</tr>
</tbody>
</table>

### Mal-area for Area of Interest

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum positive pixel value</td>
<td>4</td>
</tr>
<tr>
<td>Minimum positive pixel value</td>
<td>0.1</td>
</tr>
<tr>
<td>Sum of pixel values</td>
<td>34,202.8</td>
</tr>
<tr>
<td>Average pixel value</td>
<td>1.28</td>
</tr>
<tr>
<td>Average positive pixel value</td>
<td>1.87</td>
</tr>
<tr>
<td>Area of interest (number of pixels)</td>
<td>27,728</td>
</tr>
<tr>
<td>Area of Mal-area (number of positive pixels)</td>
<td>18,335</td>
</tr>
<tr>
<td>Area of interest covered by Mal-area</td>
<td>66.12%</td>
</tr>
</tbody>
</table>
http://www.vectormap.org/

New viewer site requires Silverlight
Opening screen
Zoom to AOI, different map choices
Distribution models for vector species
Uncertainty
Relate vector distribution to collection records
Text-based searching of point data
Details of search results for collection records
In progress...
VectorSurv – for long term providers of surveillance data

Locations

Log-in for online data input

Reports of vector trends/anomalies

Figure 7. Page 7 of 7
SUMMARY

• VectorMap is an online database for georeferenced collection records, distribution models and disease models
• Vmap = MMap + SFMap + TMap
• Vector data is fundamental for predictive surveillance models
• Future - Host and Longitudinal surveillance data
• Online collection form and Excel Mapper
Funding provided by the Global Emerging Infections Surveillance and Response System, a Division of the Armed Forces Health Surveillance Center.

Thanks also to Jamie Christensen (WorldView Inc), Clara Witt (GEIS), Jason Richardson (WRAIR), collaborators of our GEIS project (Terry Klein, Heung Chul Kim, Assaf Anyamba, A. Townsend Peterson), WRBU staff, and data contributors worldwide.

The opinions or assertions contained herein are the private views of the author, and are not to be construed as official, or as reflecting true views of the Department of the Army or the Department of Defense.