Technologies for Vector-Borne Disease Surveillance

Introduction

One million people worldwide die from mosquito-borne diseases every year.[1] In the United States, these diseases pose a significant public health threat, with some of the most common diseases being the Zika virus, West Nile virus, Chikungunya virus, dengue, and malaria.[2] Across the U.S. territories, past Chikungunya and dengue outbreaks have increased the risk for Zika, and local transmission has been reported in Puerto Rico, the U.S. Virgin Islands, and American Samoa.[3] According to CDC's reporting, the U.S. territories currently account for 80 percent of symptomatic Zika virus disease cases reported to date.[4]

This document[i]:

- Identifies vector-borne disease surveillance technologies that public health agencies can use to monitor and mitigate mosquito-related outbreaks.
- Outlines the integrated prevention, response, and mitigation activities that comprise a surveillance workflow that public health officials can use to track outbreaks and share information with the public.
- Shares best practices to develop a workflow for better decisionmaking about vector-borne disease at local and state levels.

Surveillance Technologies

Whether an agency is just beginning to develop surveillance activities or enhancing an existing workflow, several required elements serve as building blocks for an effective surveillance workflow. This includes geographic information systems (GIS) software and data collection tools, original data, and training and guidance resources. Once established, these tools can be configured in a process that supports both an agency's surveillance needs and provides critical data to national surveillance systems, like CDC's ArboNET.

If there are already current surveillance activities in place, purchasing individual tools to supplement an existing workflow is helpful and may result in a cost-savings to the agency. The tools described in this document can be used for each step of the surveillance workflow, from data analysis to map creation.

However, if a public health agency has not yet begun surveillance activities, a complete surveillance workflow is advantageous as it serves as a one-stop-shop, integrating tools and surveillance activities into a centralized solution. Workflows are understood best as ready-made packages that integrate the day to day management of surveillance tasks, leading to significant time savings and improving overall efficiency. Health departments and local organizations use two major workflows, including a paid solution developed by Esri that leverages the organization's software and tools, and a low-cost solution developed by Community Health Maps that integrates free or low-cost open source tools (see **Table 2**).

[i] *Disclaimer: The Association of State and Territorial Health Officials (ASTHO) does not endorse any of the following products. These technologies were selected because they have demonstrated their effectiveness for decisionmaking by several state health agencies, in addition to being largely platform agnostic and interoperable.*

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The following tables provide an overview of the available tools, platforms, and workflows that can be used to centralize, manage, and track an agency's surveillance tasks. The criteria used to select the tools and platforms include:

- Widespread use among health agencies or proven effectiveness.
- Usability on various operating systems (platform agnostic).
- Ability to integrate tools in a workflow.
- Low-cost or free (Esri tools can be purchased separately).

A summary of their features, functions, and capabilities is provided following the tables.

Table 1. Data collection tools and geospatial platforms that can supplement existing surveillance activities.

Developer	Platform or Tool	Function	Cost	Website
Fulcrum	Mobile Form Builder and Data Collection App	Data Collection	Paid	http://www.fulcrumapp.com/
Zerion Software	iForm Builder App	Data Collection	Paid	https://www.zerionsoftware.com/iformbuilder/
QGIS	QGIS Platform	Data Analysis Map Creation	Free	http://www.qgis.org/en/site/
Carto	Carto Builder	Data Analysis Map Creation	Free and paid options	https://carto.com/builder/

Table 2. Surveillance workflows that integrate the suite of surveillance activities.

Developer	Workflow	Function	Cost	Website
Esri	Vector-Borne Disease Surveillance and Control Workflow	Data Collection Data Analysis Map Creation	Paid	http://go.esri.com/vector-ready
Community Health Maps	CHM's workflow integrates publicly available free and low-cost accessible mapping software.	Data Collection Data Analysis Map Creation	Low-cost and free options	https://communityhealthmaps.nlm.nih.gov/

Data Collection Tools: Features, Functions, and Capabilities

Fulcrum's Mobile Form Builder and Data Collection App
Fulcrum is a mobile data collection platform that allows users to build and customize mobile forms for field data collection. Fulcrum developed the Mobile Form Builder and Data Collection app as a highly intuitive tool where forms can be customized by dragging and dropping new fields to collect GPS coordinates automatically. Data can be collected in a variety of formats including numbers, dates, audio,

and photos, which can be exported into formats like KML or shapefiles for display in a GIS platform, such as QGis, Carto or Esri's ArcGIS. Fulcrum's Mobile Form Builder and Data Collection App can be used on both iOS and Android devices and can collect data offline, which makes it a flexible option for field workers who want to use existing technology. Prices are affordable, beginning at $18 for a monthly subscription that increases with online storage purchases. Fulcrum offers a free 30-day trial.

Zerion's iFormBuilder
Zerion is a cloud-based mobile data collection platform for mobile devices that operates similar to Fulcrum. Zerion's iFormBuilder accepts over 30 types of data such as text, number, date, location (automatically collects GPS coordinates), and images, which can be collected and stored in the field offline. When users return to their office, they can download and sync their data with QGIS or Carto for visualization and analysis. iForm Builder can also be used on iOS and Android devices, but place a stronger emphasis on data security (the app is HIPAA, FISMA, and ISO 9001 compliant). iForm Builder is priced at an annual subscription fee, but users can request a free demo.

Other low-cost tools available for iOS and Android operating systems include EpiCollect and GIS Cloud. Another open source option is Open Data Kit, available only on Android devices.

Geospatial Platforms: Features, Functions, and Capabilities

QGIS
QGIS is the leading free and open source desktop GIS used by organizations who seek a low-cost alternative without compromising functionality and quality. Within a vector-borne disease surveillance workflow, QGIS is the platform used to analyze field data and generate maps. The platform's strength derives from its interoperability, supporting over 100 data formats with its large suite of geoprocessing tools. It supports most geospatial vector and raster file types and database formats, which can be visualized over Google maps and OpenStreetMap basemaps.[5] In addition, data created in QGIS can easily be imported into Esri's ArcGIS software or other design programs like InkScape or Adobe Illustrator.[6] This feature is useful for organizations with limited Esri licenses or limited access to advanced tools in ArcGIS.

QGIS is actively supported by a group of volunteers who continue to add to its growing number of capabilities, from data visualization and management, to map composition and GPS data support. Its large user community also means it is a well-documented program with widely available user resources such as free lab exercises, case studies, and an online blog. As an official project of the Open Source Geospatial Foundation, QGIS has no associated licensing costs and can be downloaded for free.

Carto's Carto Builder
Carto Builder is Carto's freely available web-based GIS platform. Web-GIS offers a distinct advantage over traditional GIS in that it uses the internet to allow clients to access information through their web browsers and work away from a server.[7] It is also cloud-based, bringing together geospatial, web-mapping tools and unique visualization capabilities. Users can analyze data and create interactive, shareable maps, such as cluster, bubble, and heat maps.[8] Visualizations can be shared on websites by generating a hyperlink or embedding maps directly into a web page.

Web-GIS is designed for a broader audience, making the program easier to use. In Carto, users can simply drag and drop data as a geospatial file format, from a spreadsheet, or as a URL onto basemaps from public data sources like the U.S. Census and Natural Earth.[9] Users can sign up for a free account for access to public data, shared resources, limited location data services and community support, or purchase a paid personal account with increased capabilities and functions for a monthly subscription fee. Enterprise accounts are also available to organizations for scalable and collaborative capabilities.

Other open source GIS platforms include DIVA-GIS and GRASS-GIS. An alternative to Carto is Mapbox, which is also a popular commercial platform.

Surveillance Workflows: Features, Functions, and Capabilities

Esri's Vector-Borne Disease Surveillance and Control Solution

Esri's Vector-Borne Disease Surveillance and Control Solution is a complete workflow that is built on the ArcGIS platform to support the myriad tasks required for vector-borne disease surveillance, from data collection to analysis and information sharing. Using the suite of Esri tools and products, it provides organizations with a wide range of apps, maps, and data to locate an event, monitor its spread, and direct intervention and outreach activities to mitigate it. The platform also provides flexible deployment options that connect mosquito control, public health staff, and the public, leading to improved decisionmaking, response time, and dispatch efforts.[10]

With the ArcGIS platform, location data can communicate essential insights to decisionmakers and the public, who can access and display data on any device. Public comments can be shared on public maps and messages can also be transmitted back to the public through the platform. Organizations must contact Esri for pricing options, which will vary based on the tools purchased. Esri published a white paper with more information on the workflow.

Using ArcGIS to Update Surveillance in Santa Cruz County

For 20 years, Santa Cruz County's Mosquito Abatement and Vector Control (MAVC) program has used GIS technology for surveillance activities. In earlier years, they created shapefiles of standing water locations, coupled them with aerial imagery to direct prevention activities, and manually entered field data into Microsoft Access. MAVC now uses ArcGIS products to automate their workflow. They developed the Mosquito Button to automate its processes. Staff now upload maps to ArcGIS Online to edit data, perform analyses, measure distances, and publish a consolidated layer via the Operations Map app for ArcGIS. On this one consolidated layer, staff can identify vulnerable communities faster and inspect and treat those sites.

Community Health Maps

Community Health Maps (CHM) was developed for organizations that are interested in a surveillance workflow, but lack the IT/GIS skills or funding to purchase software. CHM identifies free or low-cost open source tools and integrates them into a workflow that can be used by these organizations. CHM's blog describes its mission and rationale for connecting communities with low-cost mapping tools: "…community-based and minority health organizations are in a better position to serve their populations when they are able to collect and maintain their own data, rather than—or at least in

addition to—having to rely solely on national and state agencies or majority-institution partners to provide data to them."

CHM harnesses platforms and tools like QGIS and Fulcrum, which can be supported by widely available devices, empowering community groups to develop, manage, and share their own spatial data. For example, users can collect information on smart devices using Fulcrum's Mobile Form Builder and Data Collection App and use a web-GIS (e.g., QGIS) to conduct analyses, create maps, and educate communities. The workflow was specifically designed to be interoperable with Esri products and national databases such as CDC's Behavioral Risk Factor Surveillance System.[11]

CHM is a collaboration between the National Library of Medicine, the Center for Public Service Communications, and Bird's Eye View GIS, who provide original content and resources on the blog. These include mapping lab exercises, case studies, and hands-on training workshops held at national conferences and partner organization events.[12]

A Zika Surveillance Curriculum for the Medical University of South Carolina

In 2016, nursing students from the Medical University of South Carolina's College of Nursing's Population Health Class developed a surveillance curriculum with the CHM team to address the impending spread of the Zika virus. Their goal was to educate residents on prevention strategies and they began by mapping areas of increased exposure to mosquitoes and researching current Zika data. Their final curriculum encompassed survey and data collection methods, mapping workflows, and outreach activities. The workflow required minimal technology, with students using only a laptop with internet access, at least one smart device, and transportation to field sites.

Conclusion

A well-established surveillance strategy is critical as public health agencies plan for mosquito season and prepare for potential vector-borne disease outbreaks. Whether adopting new surveillance activities or seeking to enhance current practices, the tools and technologies explored in this document will strengthen an agency's ability to conduct targeted control measures to mitigate the spread of local transmission, effectively communicate with the public, and enable policymakers to make better decisions for the communities they serve.

For more guidance and resources on vector-borne disease management, please visit ASTHO's Natural Environment web page.

[1] AMCA. "Mosquito-Borne Disease." Available at http://www.mosquito.org/mosquito-borne-diseases. Accessed 5-12-2017.
[2] CDC. "Mosquito-Borne Diseases." Available at https://www.cdc.gov/niosh/topics/outdoor/mosquito-borne/. Accessed 5-12-2017.
[3] CDC. "Key Messages – Zika Virus Disease (as of 5/17/17)." Available at https://www.cdc.gov/zika/pdfs/zika-key-messages.pdf. Accessed 5-23-2017.
[4] CDC. "2017 Case Counts in the US (as of 5/12/17)." Available at https://www.cdc.gov/zika/reporting/2017-case-counts.html. Accessed 5-23-2017.

[5] Community Health Maps. "Map and Analyze Field Data with QGIS." Available at https://communityhealthmaps.nlm.nih.gov/2014/09/20/map-and-analyze-field-data-with-qgis/. Accessed 5-12-2017.
[6] Ibid.
[7] Esri. "About web GIS." Available at http://server.arcgis.com/en/server/latest/create-web-apps/windows/about-web-gis.htm. Accessed 5-12-2017.
[8] Carto. "Maps." Available at https://carto.com/docs/carto-editor/maps/. Accessed 5-19-2017.
[9] Carto. "Datasets." Available at https://carto.com/docs/carto-editor/datasets. Accessed 5-19-2017.
[10] Esri. "An Esri White Paper: ArcGIS® Empowers Faster Response for Vector-Borne Disease Surveillance and Control." Available at https://store.elecdata.com/specsheets/Esri_vector_white_paper.pdf. Accessed 5-19-2017.
[11] Community Health Maps. "An Interview with John Scott." Available at https://communityhealthmaps.nlm.nih.gov/2017/04/13/an-interview-with-john-scott/. Accessed 5-12-2017.
[12] Community Health Maps. "Remembering a Community Health Maps Milestone." Available at https://communityhealthmaps.nlm.nih.gov/2017/04/19/remembering-a-community-health-maps-milestone/. Accessed 5-12-2017.