PNNL-22767

Homeland Security

Prepared for the U.S. Department of Homeland Security
under U.S. Department of Energy Contract DE-AC05-76RL01830

# BioCat 2.0

CD Corley
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September 2013

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Pacific Northwest National Laboratory
Richland, Washington 99352

# Abstract

The U.S. Department of Homeland Security (DHS) National Biosurveillance Integration Center (NBIC) was established in 2008 with a primary mission to "(1) enhance the capability of the Federal Government to (A) rapidly identify, characterize, localize, and track a biological event of national concern by integrating and analyzing data relating to human health, animal, plant, food, and environmental monitoring systems (both national and international); and (B) disseminate alerts and other information to Member Agencies and, in coordination with (and where possible through) Member Agencies, to agencies of State, local, and tribal governments, as appropriate, to enhance the ability of such agencies to respond to a biological event of national concern; and (2) oversee development and operation of the National Biosurveillance Integration System (NBIS)." Inherent in its mission then and the broader NBIS, NBIC is concerned with the identification, understanding, and use of a variety of biosurveillance models and systems.

The goal of this project is to characterize, evaluate, classify, and catalog existing disease forecast and prediction models that could provide operational decision support for recognizing a biological event having a potentially significant impact. Additionally, gaps should be identified and recommendations made on using disease models in an operational environment to support real-time decision making.

# Acronyms and Abbreviations

| | |
|---|---|
| DHS | U.S. Department of Homeland Security |
| HHS | U.S. Department of Health and Human Services |
| IT | information technology |
| LANL | Los Alamos National Laboratory |
| NBIC | National Biosurveillance Integration Center |
| NBIS | National Biosurveillance Integration System |
| SME | subject matter expert |
| SMW | Semantic MediaWiki |
| TRL | Technology Readiness Level |
| USDA | U.S. Department of Agriculture |

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# 1.0 Introduction

The National Biosurveillance Integration Center (NBIC) mission is to enhance the capability of the Federal Government to rapidly ***identify, characterize, localize, and track a biological event of national concern*** by integrating and analyzing data relating to human health, animal, plant, food, and environmental monitoring systems (both national and international); ***and disseminate alerts*** and other information to Member Agencies and to agencies of State, local, and tribal governments, to enhance the ability of such agencies to respond to a biological event of national concern.. PNNL has supported the operational biosurveillance modeling needs of NBIC in a project funded by the U.S. Department of Homeland Security (DHS) Science and Technology Directorate (S&T) to identify, characterize, and catalog models that could be used in an operational environment.

A rich and diverse field of infectious disease modeling has emerged in the past 60 years and has advanced our understanding of population- and individual-level disease transmission dynamics, including risk factors, virulence, and spatio-temporal patterns of disease spread. These modeling techniques span domains such as biostatistical, massive agent-based, biophysical, ordinary differential equation, and ecological-niche models. Diverse data sources are being integrated into these models as well, including demographics, remotely sensed measurements and imaging, environmental measurements, and surrogate data such as news alerts and social media. Moreover, nascent research is occurring at the omics-level to aid in forecasting future epidemics; such research includes phylogenetic techniques for predicting pathogen mutations, algorithms for microbial identification in next-generation technologies, meta-genomics, and multi-scale systems biology. Yet emerging infectious diseases continue to impact health and economic security across the globe. There remains a gap in the sensitivity and specificity of these modeling forecasts designed not only to track infectious disease events but also to predict disease occurrence. For an example, one needs to look no further than the 2009 H1N1 influenza pandemic. The latency between identification and characterization of the virus's pathogenicity and transmissibility caused, perhaps, unnecessary mitigation measures such as school and business closures. Moreover, there are strong indicators that dynamics and emergence of vector-borne diseases are in flux because of, among other factors, changes in land use, human behavior, and climate.

The goal of this systematic review was to identify areas for research to characterize the viability of biosurveillance models to provide operationally relevant information to decision makers about disease events. We define a disease event to be a biological event within the context of One Health and all-hazard paradigms. These events are characterized by evidence of condition and risk. These are neither mutually exclusive nor limited to the following examples for evidence of condition: person-to-person transmission (e.g., *Mycobacterium tuberculosis*), zoonoses (e.g., *Francisella tularensis*), foodborne pathogens (e.g., *Salmonella*), vector-borne pathogens (e.g., *equine encephalitis virus*), waterborne pathogens (e.g., *Vibrio cholerae*), airborne pathogens (e.g., influenza), animal-to-animal transmission (e.g., *Aphtae epizooticae*), and plant pathogens (e.g., soybean and wheat rusts). Examples for evidence of risk are accidental or deliberate events affecting air or water quality (e.g., volcanic ash, pesticide runoff), economically motivated adulteration of the food and pharmaceutical supply, and intentional release. In the context of this article, a **biosurveillance model** is broadly defined as an abstract computational, algorithmic, statistical, or mathematical representation that produces informative output related to all-hazards event detection or event risk. The model is formulated with a priori knowledge and may ingest, process, and analyze data. A biosurveillance model may be proactive or anticipatory (e.g., used to detect or forecast an event, respectively), it may assess risk, or it may be descriptive (e.g., used to understand the dynamics or

drivers of an event). The evaluation of biosurveillance models and data sources provides key information to enable the identification of gaps and recommendations for improvements to existing models to optimize the utility of the models in an operational environment. This scientifically driven process ensures that the capabilities and limitations of biosurveillance models and data streams are understood by potential users and stakeholders, and result in a path forward toward enhancing biosurveillance capabilities.

For reference, the statement of work for PNNL's Fiscal Year 2013 (FY13) effort is provided below. The report aligns with the logical flow of our work rather than task by task.

**Task 1: Continue identification and characterization of operational biosurveillance models**

PNNL will identify, evaluate, and catalog existing syndromic surveillance, indicator systems, and event-detection biosurveillance models published during **FY12–13**. The focus of this task will be to use the attributes and approach developed in the previous work with NBIC to identify, evaluate, and catalog existing event-detection biosurveillance models.

**Subtask 1.1**: Identify syndromic surveillance, indicator systems, and operational event-detection biosurveillance models. We will first identify event-detection biosurveillance models operationally deployed by government, industry, academia, and foreign and global organizations.

**Subtask 1.2**: Evaluate models identified in Subtask 2.1 with the model characterization plan developed in the first BioCat effort. We will expand the attributes and develop quantitative metrics that will then be applied to prediction and forecast biosurveillance models.

**Subtask 1.3**: Catalog models. We will maintain and store the biosurveillance model catalog within a MediaWiki open-source wiki framework that was created under the previous work with NBIC. The catalog is hosted at http://biocat.pnnl.gov and is accessible via the web. and access is controlled through user/password authentication.

**Subtask 1.4**: Collaboration and Sharing. We will travel to meet with the Sponsor, collaborate with analysts to ensure BioCat's operational relevance. Additionally, PNNL may submit and participate in biosurveillance- or biodefense-related conferences to promote the NBIC/NBIS and BioCat for community use.

**Task 2: Back-identify, characterize and catalog operational biosurveillance models**

PNNL will identify, evaluate, and catalog existing syndromic surveillance, indicator systems, and event-detection biosurveillance models, published during calendar year 2011 and 2012 (CY11–12). The focus of this task will be to use the attributes and approach developed in the previous work with NBIC to identify, evaluate, and catalog existing event-detection biosurveillance models.

**Subtask 2.1**: Identify syndromic surveillance, indication, and operational event-detection biosurveillance models. We will first identify event-detection biosurveillance models operationally deployed by government, industry, foreign and global organizations during CY11–12.

**Subtask 2.2**: Evaluate models identified in Subtask 2.1 with the model characterization plan developed in BioCat Phase 1. Leveraging the quantitative analysis and through following the vetted characterization plan, each event-detection biosurveillance model will be evaluated. Additionally, PNNL will evaluate models not yet evaluated discovered during BioCat Phase 1.

**Subtask 2.3**: Review the discovered models from BioCat phase 1 and identify models with peer-reviewed conference publications and abstracts. Then evaluate those models with the same rubric as in Task 1.

**Subtask 2.4**: Catalog models. We will maintain and store the biosurveillance model catalog within a MediaWiki open-source wiki framework that was created under the previous work with NBIC. The catalog is hosted at http://biocat.pnnl.gov and is accessible via the web, and access is controlled through user/password authentication.

**Task 3: Maintain the BioCat for NBIS/NBIC, and Update Software**

PNNL will host the BioCat for the DHS Office of Health Affairs NBIS/NBIC. The model catalog continues to provide value to biosurveillance stakeholders across the government and academia. BioCat is located at PNNL on a webserver that was purchased by DHS S&T and is accessible via the Internet. The software framework on which BioCat is built must be updated periodically with security patches and modified configurations.

**Subtask 3.1**: PNNL will ensure the BioCat remains operational and accessible via the internet.

**Subtask 3.2**: A variety of projects at PNNL utilize the Knowledge Encapsulation Framework (KEF) software and fund the development of new software and upgrades. Funding under this subtask will ensure that the upgrades developed for other programs are integrated into BioCat.

**Subtask 3.3**: Coordinate with interagency biosurveillance efforts, and where possible leverage interagency resources and integrate within BioCat. PNNL will also integrate the NBIC's open RSS feed within the BioCat to be viewable by BioCat users.

# 2.0 Literature Selection and Processing

To provide a comprehensive list of biosurveillance models, the PNNL team took two approaches. In the first approach, PNNL staff contacted subject matter experts (SMEs) in academia and government to discuss existing biosurveillance models. A literature search (the active identification of existing information sources most relevant to the research question or need) was performed in the second approach to comprehensively identify biosurveillance models in the scientific, grey, and limited-distribution literature. One of the main goals of the FY13 funding for BioCat was to identify relevant biosurveillance literature since the end of the last increment of funding in 2011. We identified and pursued several lines of inquiry.

1. Identify people and institutions working in the domain of biosurveillance.

2. Scope agents, pathogens and toxins of interest to NBIC.

3. Conduct targeted literature searching in salient databases from 2011 to present.

4. Vet literature with subject matter experts.

5. Acquire materials for evaluation.

6. Refine list of papers for evaluation based on NBIC prioritization.

7. Import literature citations into Drupal (open source content management platform).

The first task was to update our people and institutions list. This effort involved reviewing the original list from the previous effort and updating contact information and websites of experts and research institutions focused on the topic of biosurveillance. This information is provided in Appendix A.

The second task was to understand the agents, pathogens, and toxins of interest to NBIC. We received nine lists, including several from the Centers for Disease Control and Prevention (CDC) and the U.S. Department of Agriculture (USDA) as provided in Appendix B. Extensive effort was taken to de-duplicate these lists and develop a list of synonyms for each (Appendix C).

Following the de-duplication of the lists of interest, targeted literature searches were conducted. Twelve research databases were queried (Table 2.1). Four additional databases were used in the first round of BioCat literature identification in 2010–2011. By the time targeted searches were performed in 2013, GeoRef, Pollution Abstracts, and Toxicology Abstracts had been cancelled at PNNL due to low use.

**Table 2.1.** Databases Used to Identify Biosurveillance Modeling Literature

| Database | Database Provider |
|---|---|
| Academic Search Complete | EBSCOHost; Open Source Center |
| ASFA: Aquatic Sciences and Fisheries Abstracts | ProQuest; PNNL Library |
| BioOne Abstracts and Indexes | BioOne, PNNL Library |
| Compendex | Engineering Village, PNNL Library |
| INSPEC | Engineering Village, PNNL Library |
| NTIS | Engineering Village, PNNL Library |
| DTIC (private version) | Defense Technical Information Center |
| Environment Index | EBSCOHost; Open Source Center |
| GreenFILE | EBSCOHost; Open Source Center |
| Google Scholar | Google |
| Homeland Security Digital Library | Naval Postgraduate School |
| International Security & Counter Terrorism Reference Center | EBSCOHost; Open Source Center |
| MEDLINE (through Web of Knowledge portal) | Thomson Reuters, PNNL Library |
| Military & Government Collection | EBSCOHost; Open Source Center |
| Oceanic Abstracts | ProQuest; PNNL Library |
| Scirus | |
| Scopus | EBSCOHost; Open Source Center |
| Water Resources Abstracts | ProQuest; PNNL Library |
| Web of Science (Science edition), Conference Proceedings Citation Index (Science; Social Sciences & Humanities) | Thomson Reuters, PNNL Library |

The agents, pathogens and toxins listed in Appendix B were combined with additional keywords (Table 2.2) to refine search results. An example search string: [one disease, toxin, agent, pathogen from Appendix C and all its synonyms (Boolean Operator OR linking the synonyms together)] AND [one or more keywords from Table 2.2]. The dates were limited to 01-01-2011 to the date that the search was executed. Methods of truncation, search limiters, etc. used were dependent upon the database requirements. In some cases it was useful to refine the search results with the NOT Boolean Operator to exclude extraneous citations focused on AIDS, HIV, STD, cancers, etc. The resulting relevant literature was downloaded into EndNote X6 bibliographic management software for portability, ease of use, export capability, and document storage solutions.

**Table 2.2.** Additional Keywords Used to Refine and Identify Biosurveillance Modeling Literature

| Search Terms and Phrases | |
|---|---|
| Adulteration and food | Early recognition |
| Adulteration and pharmaceuticals | Epidemic model* |
| Biolog* or pathogen or toxin or disease model characterization | Event detection and biolog* or pathogen or toxin |
| Biological risk assessment | Event detection biosurveillance |
| Biosurveillance | Event-based biosurveillance |
| "Biosurveillance intelligence" | Foodborne disease* detection or surveillance or outbreak |
| Bioterror* agents | Forecast + GIS or GPS or remote sensing |
| Bioterror* and model | Geodemographics |
| Bioterror* food model | Geoinformatics biosurveillance |
| CBRN model* | Geosurveillance |
| Communicable disease detection or model* | Global biosurveillance |
| Crop disease model* | Global surveillance |
| Disease and weather forecast | Health intelligence |
| Disease detection | Health security |
| Disease epidemic | "Infectious disease" surveillance or model* |
| Disease forecast | Insect risk + model |
| Disease forecast* model | Model +predictive, +probabilistic, +projection, +forecast |
| Disease indicators and/or warnings | Outbreak prediction |
| Disease management | Outbreak forecast* |
| Disease map* | Pathogen detection/recognition/surveillance/prediction + model* |
| Disease modeling | Population dynamic* and outbreak |
| Disease or bioterror* risk | Predict* or project* or forecast* or "early warn*" or "early detect*" and model* |
| Disease or outbreak origin | Predictive model |
| Disease outbreak or emergence or spread or transmission | Predictive model* and disease + infectious + epidemic |
| Disease patterns | Remote sensing and disease and/or forecast and/or model |
| Disease regulation | Risk map* and disease model* |
| Disease risk or forecast or detection | Sentinel surveillance |
| Disease simulation | Social disruption and disease or pathogen or toxin |

**Table 2.2.** (contd)

| Search Terms and Phrases | |
|---|---|
| Disease source | Social networks, social network analysis and biosurveillance |
| Disease surveillance and infectious | Spatial analysis disease |
| Disease transmission | Spatial disease model* |
| Disease warning | Spatial epidemiology |
| Drug contamination or surveillance or outbreak | Surveillance or security |
| Early detection | Syndromic surveillance |
| | Vector borne (or vector-borne) disease model |

After each database in Table 2.1 was searched, a batch export of the citations with abstracts was generated in Microsoft Word®. The citations were evaluated by SMEs for potential to contain predictive or forecasting models focused on biosurveillance. Relevant abstracts were flagged with a color: green for Yes, yellow for Maybe. Abstracts that lacked a clear relevance to the research effort were not flagged. Each citation batch was vetted twice, with the first pass conducted by a postdoctoral scientist and the second pass was conducted by a research staff scientist with expertise in epidemiology or microbiology. If the SME disagreed with the initial assessment, the SME judgment was accepted.

Once the batch assessments were complete, the results were reviewed by the data analyst. The data analyst created Group folders (Yes, Maybe, No) in each database's respective EndNote library and moved each citation to the appropriate folder based on the assessment completed in the previous step. Literature in the Yes and Maybe categories were acquired in PDF format. Once these materials were received, the PDF files were stored with the citation in the EndNote database.

The literature citations were prepared for import into Drupal, the web-based content management platform used by BioCat. All of the flagged Yes citations from each database EndNote library were copied into a new library file. Because of the overlap between abstracting/indexing coverage in major scientific databases, duplicate records were identified and removed. The same process was applied to the Maybe citations. This effort resulted in master EndNote libraries consisting of only those citations that met our newly vetted evaluation metrics criteria. Each of these libraries was imported into Drupal separately. As the Yes citations were imported, they were tagged Yes (n=447). As the Maybe citations were imported, they were tagged Maybe (n=1383). The citations that lacked a clear relevance to the research effort were not imported to BioCat (n=26,824).

After the previous steps were completed, a prioritized list of agents was requested from NBIC. From the 281 unique pathogens, toxins, and agents extracted from the nine priority lists (see Appendix B and Appendix C), the client provided PNNL with a smaller subset list of sixteen prioritized agents. These agents are those for which the NBIC has pressing information needs (see Appendix D). Using this smaller prioritized list of agents, the PNNL team queried the EndNote database to identify all of the citations matching these agents and meeting the Yes criteria (n=96). See Section 3.0 for detailed description of the model evaluation process and results.

# 3.0 Model Evaluations

This work was conducted in part to characterize published models that are capable of predicting disease events in order to determine opportunities for expanded research and to define operational readiness levels. Ultimately, practitioners need to be able to access and then operate these models without significant reprogramming. The model's forecasts or predictions need to have a known precision or error rate. An operationally ready model must also be mature. The PNNL team has expended a significant effort to address this last requirement. In partnership with the Los Alamos National Laboratory (LANL), a set of metrics was developed that enhance the attributes of biosurveillance models that PNNL co-authored during the Phase 1 BioCat project. The LANL team was qualified to contribute to developing the model metrics through their leadership in a Defense Threat Reduction Agency-sponsored effort to evaluate biosurveillance *data* sources. Over the course of three virtual meetings, the PNNL and LANL teams derived evaluation metrics to be used to assess disease models. The result of the discussions led to the PNNL team developing multiple metrics organized into three levels with each tier requiring greater domain knowledge in order to complete the evaluation. The metrics we recommend are enumerated in Appendix E, *Disease Forecast and Prediction Model Evaluation Metrics & Definitions*.

**Given the potential importance of these models to global health security, it is essential to develop a categorization scheme that defines a model's viability for use in an operational setting. none exists, but one possibility is illustrated in the following discussion, based upon the readiness level" (TRL) originally developed by NASA.[1] NASA TRL levels were not designed to apply to modeling and simulation, much less biosurveillance models, so the definitions require modification. An initial modification of these definitions is shown in**

Table 3.1. In such a scheme, the models are characterized based on how the model was validated, what type of data was used to validate the model, and the validity of data used to create the model.

**Currently, the verification and validation (V&V) of predictive models, regardless of realm of application, is an area that requires better definition and techniques. The results of model V&V can be used in the definition of model operational readiness; however, the readiness level definitions must also be accompanied by data validation, uncertainty quantification, and model fitness-for-use evaluations, many of which are areas of active research. Clarity in the definition of readiness levels and the criteria to achieve upper levels will enable confidence in the ability to consistently assign readiness levels to models and lead to enhanced value to decision makers. Further development of the operational readiness level definitions and assignment criteria for disease prediction models are needed in order to evaluate the usefulness of this approach in an operational environment. Public health analysts and decision makers are in need of evidence-based guidance and the value of operational readiness levels for the models on which they depend cannot be overstated. PNNL recommends rigorous investigation to fully outline the criterion for each of the proposed operational readiness levels defined in**

Table 3.1. It is also recommended that the viability of a particular model should be assessed through analytical case studies before its use in an operational setting.

[1] Mankins JC. 1995. *Technology Readiness Levels A White Paper*. Advanced Concepts Office, Office of Space Access and Technology, National Aeronautics and Space Administration.

**Table 3.1.** Initial Definitions of Operational Readiness Levels for Disease Prediction Models

| Level | Definition |
|---|---|
| 1 | Research only reported on observed information |
| 2 | A constructed model which has yet to be applied to data (or The model theory has been developed based on observed or hypothesized information) |
| 3 | The model has been created but has not been validated |
| 4 | The model has been verified and validated |
| 5 | The model has been demonstrated as useful but for only its original location (pathogen or population) and is still being adjusted |
| 6 | The model has been demonstrated as useful in both its original location (pathogen or population) as well as an independent location (pathogen or population) |
| 7…n | Further study is needed to explicitly delineate the criterion for additional Technology Readiness Levels |

As revealed in Section 2.0, NBIC identified sixteen prioritized agents of interest (Appendix D). Using this list in conjunction with the papers that met our SME requirements, we identified 96 papers ready for evaluation. Based on time and staffing constraints, Web of Science and Google Scholar were used to identify the number of times these articles were cited since publication. The articles with post-publication citations (n=61) were considered candidates for evaluation. Twenty-four articles were fully evaluated and curated in BioCat using the new evaluation metrics (Appendix E). These articles and the evaluation metrics are discussed in Section 3.0.

**Table 3.2.** Client Priority Agent List

| Agent | No. of Articles | No. Articles with Citations | No. Evaluated |
|---|---|---|---|
| *Bacillus anthracis* | 4 | 0 | 0 |
| Botulinum toxin | 0 | 0 | 0 |
| *Burkholderia mallei* | 0 | 0 | 0 |
| *Burkholderia pseudomallei* | 0 | 0 | 0 |
| Chlorpyrifos (Dursban) | - | - | - |
| Citrus Greening; Huanglongbing (HLB) of citrus; *Candidatus liberibacter americanus* | 0 | 0 | 0 |
| Endosulfan | - | - | - |
| Foot and Mouth Disease (FMD) | 13 | 6 | 2 |
| *Francisella tularensis* | 2 | 1 | 1 |
| Influenza (pandemic) | 52 | 35 | 16 |
| *Ralstonia solanacearum* | 0 | 0 | 0 |
| Rinderpest virus | 0 | 0 | 0 |
| SARS | 8 | 7 | 0 |
| Variola (major and minor) | 3 | 2 | 2 |
| Viral hemorrhagic fevers including Ebola and Marburg | 6 | 4 | 3 |
| *Yersinia pestis* | 8 | 6 | 0 |
| **Total YES citations** | **96 Articles** | **61 with Citations** | **24 Evaluated** |

The following are the citations for the 24 articles that were fully evaluated.

**Influenza, pandemic**


Araz, OM, et al. 2011, "A Simulation Model for Policy Decision Analysis: A Case of Pandemic Influenza on a University Campus." Journal of Simulation 5(2):89-100.

Araz, OM, et al. 2012, "Simulation Modeling for Pandemic Decision Making: A Case Study with Bi-Criteria Analysis on School Closures." Decision Support Systems 55(2):564-75.

Baker, PRA, et al. 2011, "Epidemiologic Modeling with Flusurge for Pandemic (H1N1) 2009 Outbreak, Queensland, Australia." Emerging Infectious Diseases 17(9):1608-14.

Dorigatti, I, et al. 2012, "A New Approach to Characterising Infectious Disease Transmission Dynamics from Sentinel Surveillance: Application to the Italian 2009-2010 A/H1N1 Influenza Pandemic." Epidemics 4(1):9-21.

Gupta, SD, et al. 2011, "Modeling of H1N1 Outbreak in Rajasthan: Methods and Approaches." Indian Journal of Community Medicine 36(1):36-38.

Inaida, S, et al. 2011, "Geographic Trends and Spread of the Pandemic (H1N1) 2009 in the Metropolitan Areas of Japan Studied from the National Sentinel Data." Japanese Journal of Infectious Diseases 64(6):473-81.

Jin, Z, et al. 2011, "Modelling and Analysis of Influenza A (H1N1) on Networks." BMC Public Health 11(Suppl 1): 59.

Lee, VJ, et al. 2011, "Comparability of Different Methods for Estimating Influenza Infection Rates over a Single Epidemic Wave." American Journal of Epidemiology 174(4):468-78.

Lee, VJ, et al. 2011, "A Clinical Diagnostic Model for Predicting Influenza among Young Adult Military Personnel with Febrile Respiratory Illness in Singapore." PLoS ONE 6(3): e17468.

Loganathan, P, et al. 2011, "Towards Forecasting Flu Dynamics Using a Regionalized State Space Model." In *International Symposium on Advanced Control of Industrial Processes, ADCONIP 2011*, pp. 175-80.

Matrajt, L, and IM Longini, Jr. 2012, "Critical Immune and Vaccination Thresholds for Determining Multiple Influenza Epidemic Waves." Epidemics 4(1):22-32.

Nishiura, H, G Chowell, and C Castillo-Chavez. 2011, "Did Modeling Overestimate the Transmission Potential of Pandemic (H1N1-2009)? Sample Size Estimation for Post-Epidemic Seroepidemiological Studies." PloS ONE 6(3): e17908.

Rios-Soto, KR, B Song, and C Castillo-Chavez. 2011, "Epidemic Spread of Influenza Viruses: The Impact of Transient Populations on Disease Dynamics." Mathematical Biosciences and Engineering 8(1):199-222.

Sharomi, O, et al. 2011, “Modelling the Transmission Dynamics and Control of the Novel 2009 Swine Influenza (H1n1) Pandemic.” Bulletin of Mathematical Biology 73(3): 515-548.

Smieszek, T, et al. 2011, “Reconstructing the 2003/2004 H3n2 Influenza Epidemic in Switzerland with a Spatially Explicit, Individual-Based Model.” BMC Infectious Diseases 11:115.

Torres, SF, et al. 2012, “High Mortality in Patients with Influenza A pH1N1 2009 Admitted to a Pediatric Intensive Care Unit: A Predictive Model of Mortality.” Pediatric Critical Care Medicine 13(2): e78-e83.

***Francisella tularensis***

Rydén, P, et al. 2012, “Outbreaks of Tularemia in a Boreal Forest Region Depends on Mosquito Prevalence.” Journal of Infectious Diseases 205(2):297-304.

**Foot and Mouth Disease**

Dion, E, L VanSchalkwyk, and EF Lambin. 2011, “The Landscape Epidemiology of Foot-and-Mouth Disease in South Africa: A Spatially Explicit Multi-Agent Simulation.” Ecological Modelling 222(13):2059-72.

Sanson, RL, et al. 2011, “Foot and Mouth Disease Model Verification and 'Relative Validation' through a Formal Model Comparison.” Revue scientifique et technique (International Office of Epizootics) 30(2):527-40.

**Variola**

Fuller, T, et al. 2011, “Using Remote Sensing to Map the Risk of Human Monkeypox Virus in the Congo Basin.” EcoHealth 8(1):14-25.

McKinley, TJ, et al. 2013, In Press, “Simulation-Based Bayesian Inference for Epidemic Models.” Computational Statistics and Data Analysis.

**Viral Hemorrhagic Fevers**

Gale, P, et al. 2012, “Impact of Climate Change on Risk of Incursion of Crimean-Congo Haemorrhagic Fever Virus in Livestock in Europe through Migratory Birds.” Journal of Applied Microbiology 112(2):246-57.

Medeiros, LCdC, et al. 2011, “Modeling the Dynamic Transmission of Dengue Fever: Investigating Disease Persistence.” PLoS Neglected Tropical Diseases 5(1):e942.

Wei, L, et al. 2011, “Using Geographic Information System-Based Ecologic Niche Models to Forecast the Risk of Hantavirus Infection in Shandong Province, China.” American Journal of Tropical Medicine and Hygiene 84(3):497-503.

After the 24 articles were evaluated, the PNNL SMEs (one epidemiologist and one microbiologist) identified several papers with distinctive or significant methodology or research conclusions. These papers are summarized in the following bullets.

- Inaida et al. (2011) applied kriging to influenza-like illness data to produce smoother spatial estimates of influenza incidence.
- Araz et al. (2011) evaluated the efficacy of social distancing and other mitigation practices for influenza transmission on a university campus, based on the campus response plan. They performed sensitivity analysis of the model parameters to identify the primary drivers of the changes in transmission.
- Dion et al (2011) performed a landscape analysis of cattle-buffalo contact near Kruger National Park in South Africa. Although not directly modeling foot and mouth disease, the identification of areas of greater likelihood for cattle-buffalo contact may serve as a proxy estimate of disease transmission risk. In the sensitivity analysis of the model parameters, they included two-way interaction terms.
- Gale et al. (2011) predicted and forecast the geographic spread of Crimean-Congo hemorrhagic fever, taking into account the impact of bird and tick populations in disease movement.
- Wei et al. (2011) do an excellent job clearly describing the model, the input data (source of input data), as well as type of data being fed into the model (e.g., continuous versus categorical). The high transparency of the model (not so clear in other publications) makes it possible for others to provide an independent verification and validation of the predictions and forecasts made in the publication.

# 4.0 BioCat 2.0 Website

BioCat has been developed and managed as a web-based system to maximize access by end users. Using a content management system was an important first step, because it allowed the use of existing code development and technology to create a structure for the website. The use of a content management system also enabled easy to use search and organization of information stored in the BioCat database. Login-based user permissions limit access and view/edit privileges.. Since the initial development of the BioCat website, the needs and implementation of the website have evolved, as described in this section.

## 4.1 Needs and Limitations of the BioCat 1.0 Website

In the first version of BioCat, Semantic MediaWiki (SMW) was the content management system. This system enables protecting the BioCat information from individuals who have not specifically been granted access. However, SMW also brought a number of limitations and challenges. The team wanted to have the ability to give different users permission to edit only certain parts of the information. SMW only allows someone to edit all the information or none of it. The team also wanted to track which users were editing what information and to enable the evaluation of models in an organized workflow (explained later). SMW did not support these functions.

## 4.2 Updating Software to Meet the Needs of BioCat 2.0

Given the limitations presented by SMW, a new content management system was sought for BioCat 2.0. The development team suggested another web-based content management platform called Drupal. Like SMW, Drupal is open source software, meaning that it is free to download and use. The open source model enables developers to constantly collaborate to update, fix and expand Drupal features and capabilities. As a result Drupal has a greater capacity for growth, variety and the ability to meet a far wider range of uses.

### 4.2.1 Benefits of the Drupal Web-Based Content Management Platform

Drupal has the benefit of being well supported and widely used. It has been adopted as a favorite among content management systems, especially in the U.S. government, including DHS. The community that has been built around Drupal allows collaboration, support, and development among hundreds of thousands of developers with different skill sets and experience. Drupal allows the development of new website add-on features that work with the original system, and those features can then be shared and used by others. Drupal is powerful enough to make many different features possible on a website, so Drupal is well positioned to support future BioCat development if needed.

One add-on feature that is already implemented in BioCat is called "Biblio." Biblio is a bibliography tool for the management and display of lists of scholarly publications. It supports a number of formats when importing, exporting, or displaying the publications information, including BibTex, which was the format used for BioCat publications. Biblio also handles formatting directly on the webpages, so we can display it in APA, Chicago, and many other scholarly publication formats. This is handled by Drupal directly, rather than requiring the information to be manually entered in all the desired formats.

Drupal enables greater flexibility and control over user access and editing privileges. Different users can be access different content areas, rather than all or none. ifferent users access to change only certain parts of content, rather than all or none. Drupal also tracks how much work has been completed. These options allow BioCat to have a workflow in which individuals with different levels of knowledge can review specific content according to their permissions and then pass it on to the next person in a multi-stage review process that more efficiently uses different levels of expertise.

### 4.2.2 Implementation of Publications Review Workflow for BioCat

The "workflow" concept for BioCat was implemented in Drupal. The publication review process has been divided into multiple defined levels of review, each of which must be performed before an evaluation is considered complete. Once the publications are imported, they are deemed "Level 1." At Level 1, interns completed the preliminary information. If the publication cannot be reviewed for some reason, for example if it is in a language no one can read, it is marked as "cannot evaluate," and it will be removed from the workflow. If they are unsure about any information that they have filled in, the document can be flagged as needing a second look, which notifies upper-level reviewers to double check the inputted information. Publications deemed to be neither an event prediction nor an event forecast model are removed from the workflow when the Level 1 review is marked complete. All other completed Level 1 publications progress to Level 2 review.

In Level 2, additional information is entered about the model. As in Level 1, a second look may be requested if there is uncertainty regarding the review. Once the Level 2 review is marked complete, it passes to Level 3. In Level 3, SMEs add additional information to complete the review. Once the publication review is marked as complete the publication is removed from the workflow.

Each of these Levels has a web page listing all the publications that are in that Level, so anyone with access to those workflow levels can readily view the publications in the respective workflows. There are also pages to list publications that are completed, closed, unable to be evaluated, and needing second looks. This enables anyone in the workflow process to quickly identify tasks and access the relevant publications.

A user registration process is used to control access to the BioCat site and to the workflow levels. Users must create an account and be logged in before seeing any content on the website. In addition, accounts also must be approved, which enables to the ability to allow or deny each user's access. In addition to controlling site access, user registration enables tracking who uses and edits the site. Without user registration, there is no way to track this in formation. Moreover, content interactions and changes can be tracked; it is possible to revert content to an earlier version if necessary and to identify which user(s) is responsible if the site is misused.

Each user account can have its own set of permissions that determine what the user can see or change with great granularity (e.g., a publication date). Certain groups of people can be given similar sets of permissions. In BioCat, all users with an approved account can see any publications. Users with the corresponding permissions can edit citations. Users whose account is marked as Level 1 can only see the Level 1 workflow pages, and can only add/edit Level 1 review information. Users with Level 2 accounts can see and edit Levels 1 and 2, while Level 3 users can see and edit information at all three levels.

### 4.2.3 Site Administration Features

Site administrators can see and edit all workflow levels and can edit any part of a publication being reviewed. In addition, there are a number of pages with access restricted only to administrators. One of these pages contains user information and enables administrators to see all the accounts for the website. In addition to a list of users, demographics are also provided, including charts displaying e-mail domain type and organization affiliation type. This information is collected as part of the account creation process. Site administrators also have access to pages that list what publications have been marked as closed, completed, or cannot be evaluated.

### 4.2.4 Filtered Display of Content with Faceted Browsing

For anyone viewing a list of all the publications on the site, one of the most helpful tools that Drupal enables us to implement is "faceted browsing". Faceted browsing filters a publications list and displays only those publications that meet user-selected criteria.[2] Normally, the list of publications that any logged-in user can see simply shows every publication on the website. A user looking for a specific publication would need to search for it, which means they would need to know some part of its name. However, users may often be looking for certain *types* of publications, not necessarily a particular one. Or

[2] Stefaner, M. (2009). Dynamic Taxonomies and Faceted Search: Theory, Practice and Experience. New York, NY, Springer .

they may not know exactly what publication they are looking for, but they may know certain things about it, such as what year it was published or what type of publication it is. With Drupal, publication information can be evaluated and the information that might matter to a browsing user can be expressed as content criteria. We can provide these content criteria as options (facets) next to the list. When a user selects their criteria of interest, the publication list automatically updates to show only publications that match those criteria. For example, if someone only wants to view publications that are conference papers, they simply select "Conference paper" under the "Filter by Publication Type" facet. The list will then show only conference papers, eliminating the need to browse through the full publication list looking for only conference papers.

### 4.2.5 Current Software for BioCat 2.0 Website

The following are Linux server requirements for BioCat as it has been built in Drupal:

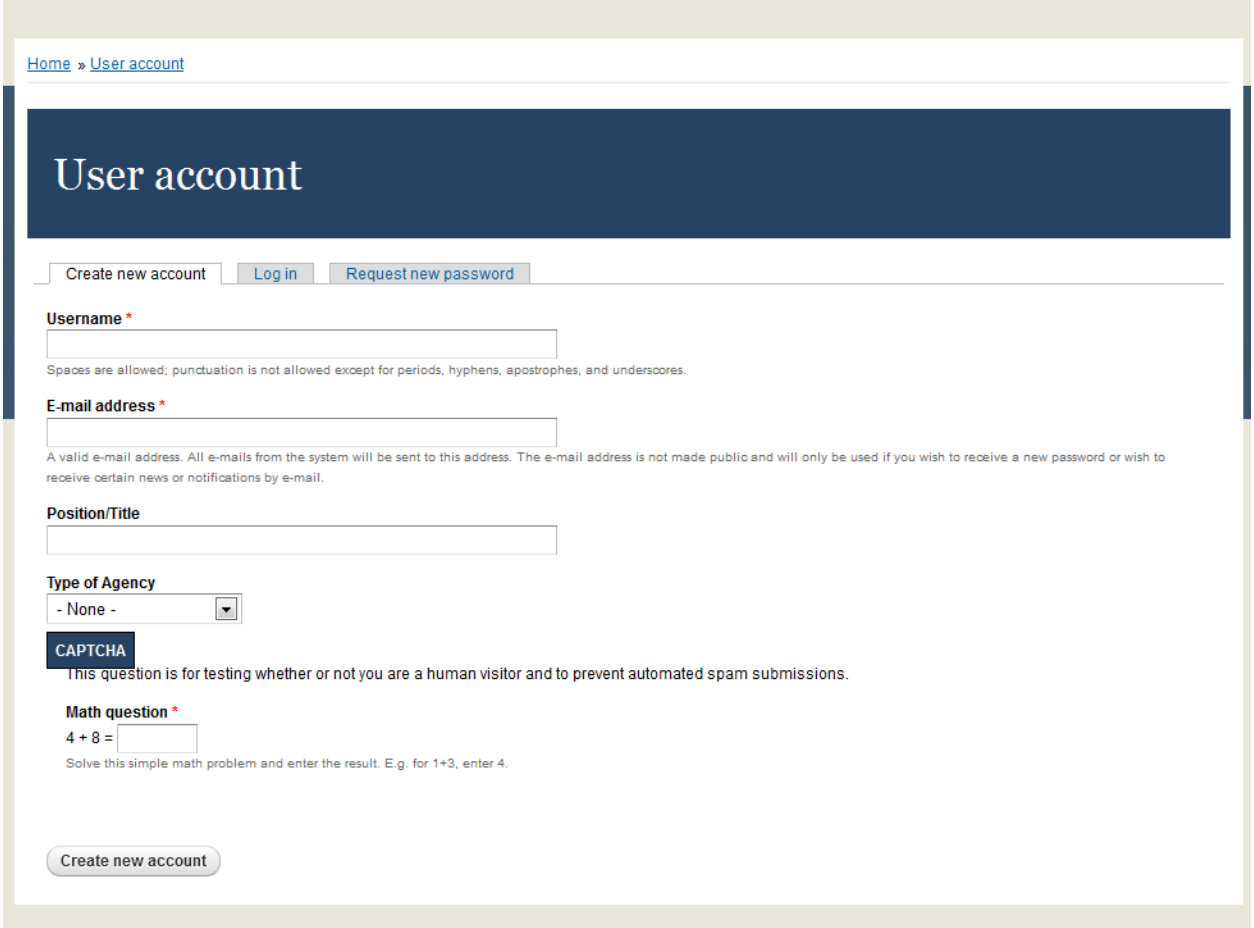
- A minimum of 15 MB of disk space (60 MB preferred) for the installation, more for the database
- Apache, Nginx, or Microsoft IIS (server software)
- MySQL 5.0.15 or higher with PHP data objects (PDO), PostgreSQL 8.3 or higher with PDO, SQLite 3.3.7 or higher (open source database)
- PHP 5.2.5 or higher (scripting and programming language)
- Drush (a command line shell and scripting interface for Drupal)
- PHP modules: mod rewrite, apc, curl, GD library, ImageMagick, MB String, ldap, mysql, mssql, pear, xml serializer.

## 4.3 Visual Tour of the BioCat 2.0 Website

An unregistered site visitor cannot log in and does not have access to any content on the BioCat website. The only links available to visitors are to register/login, to contact us, or to use the DHS navigation at the bottom of the page.


What an Unregistered Visitor to BioCat Sees

On the registration page, BioCat collects a username and email, as well as some preliminary information about the user. The registration must be approved by someone with administrative privileges on the website, who assigns a role to the new user before the user can log in and use the website.

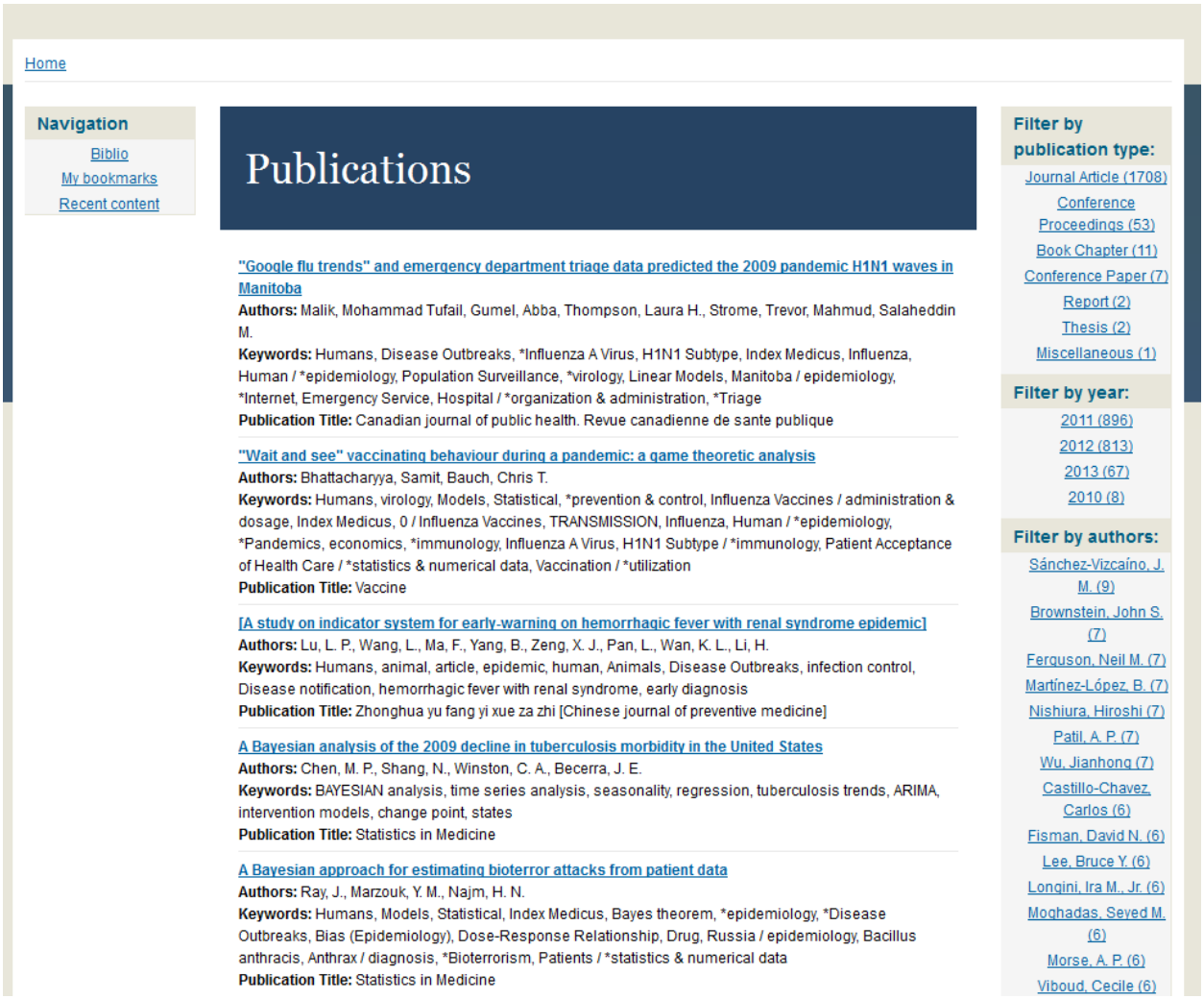



Registration Page for New User Accounts

Once users have an account and can log in, access to the site is based on the user roles that each user has been assigned by the site administrator. In the example here, a general user now has the option at the top of the page to view publications, as well as the ability to search the website.


Publications List and Search Options Available to General Users

The publications page lists a short summary of all the publications on the site. In addition to the titles, the page lists authors, keywords, and the titles of the publication from which each publication was taken. By default, the page lists all the publications alphabetically, 50 entries at a time.

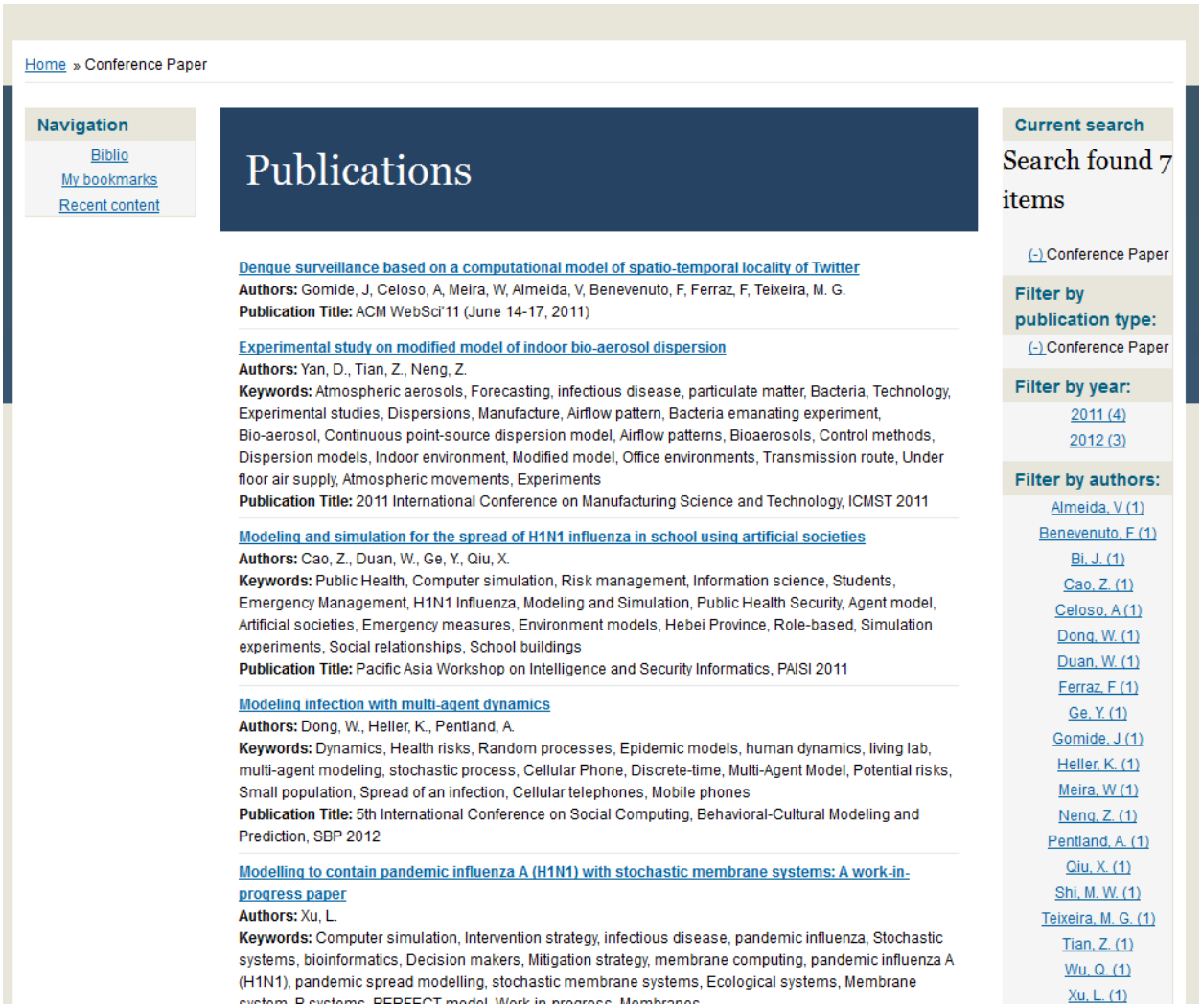


Publications Page with Default Alphabetical Listing and Filtering Criteria Options

Criteria on the right side of the publications list enable users to narrow their search via faceted browsing. Each of these criteria list some of the most common results for each category. The exact number of list entries in that category are listed in parentheses after it. For example, if someone only wanted to see conference papers, they would select **conference paper** under **Publication Type**:


Choosing to Filter the Publications List by **Conference Paper** Publication Type

The page will update according to what criteria the user chooses as a search filter. In this case, the page reloads to show only those seven conference papers, eliminating the need to search through all the entries for this single publication type.

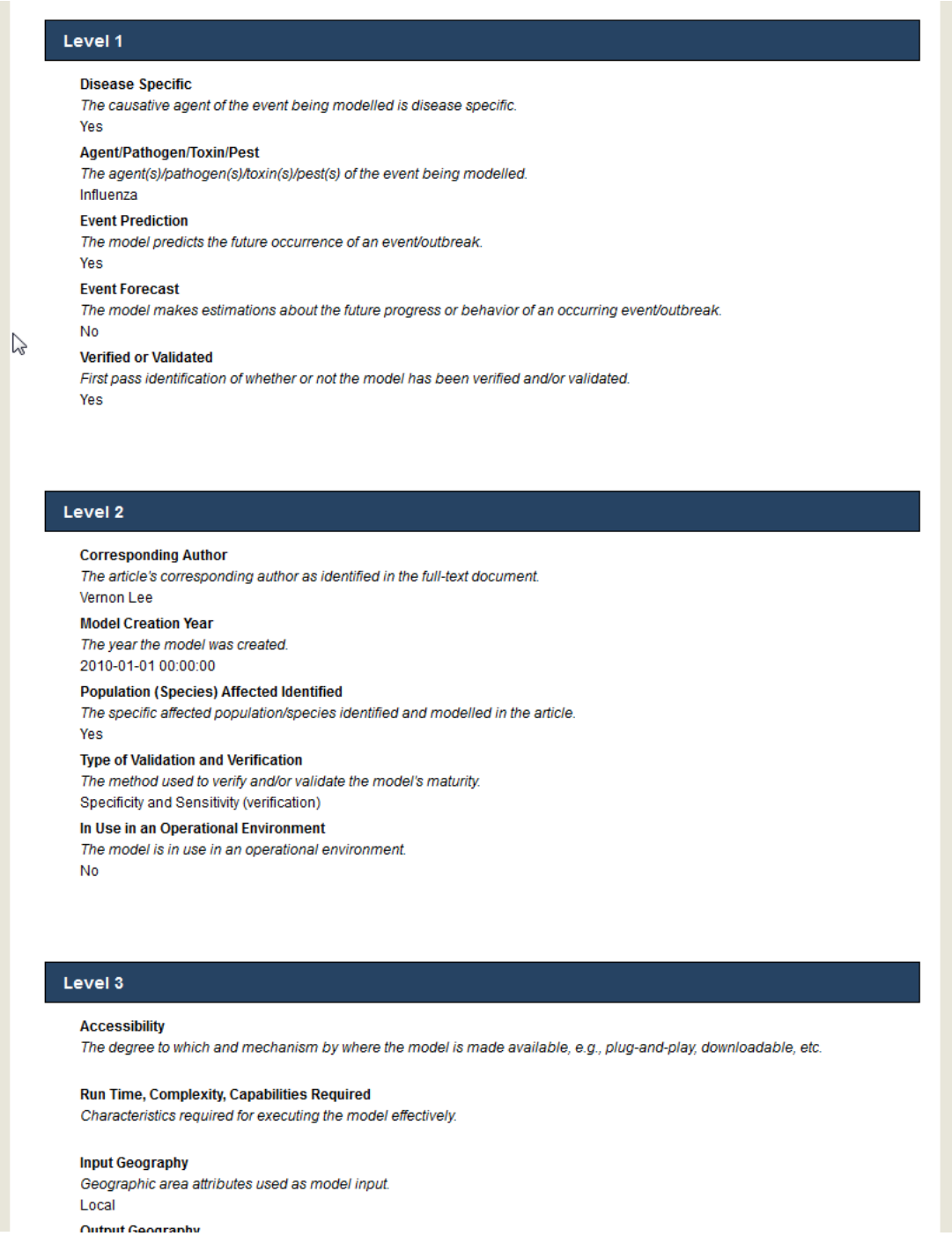



Publications List Filtered by **Conference Paper** Publication Type

If the user selects one of the publications, BioCat will display a page that shows more details about it. General users will only be able to see the publication information. Here the user has selected the first publication on the previous list. Note that the links at the bottom allow the user to search Google Scholar for this publication, or to add it as a bookmark so that the user can look it up quickly on the **My bookmarks** page (linked in the left navigation) later when revisiting BioCat.


Example of Publication Information for One Publication

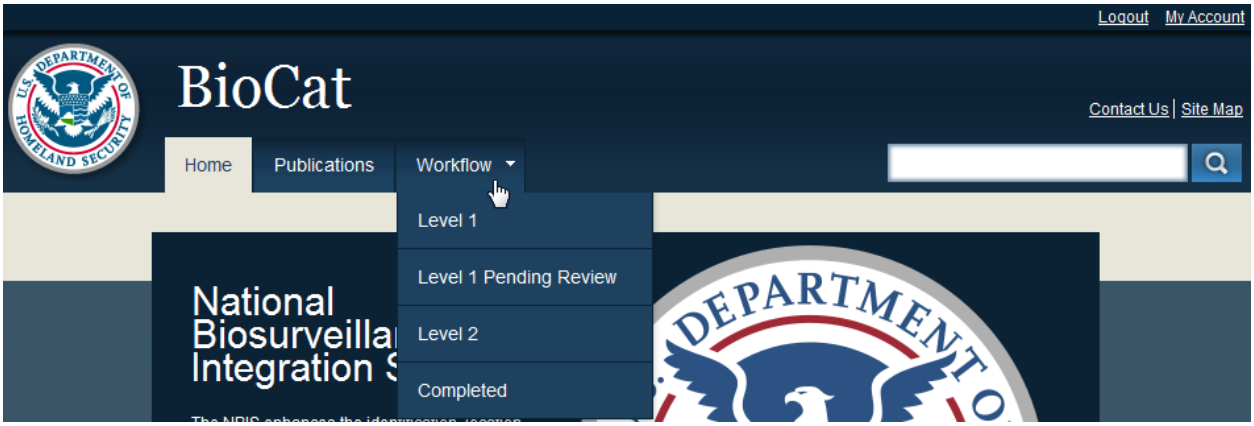
If a user has been approved as a member of the review workflow, the user will also be able to see more details about the publication, particularly about how the review process has been filled out so far.




Workflow Information View Accessible to Authorized Review Editors

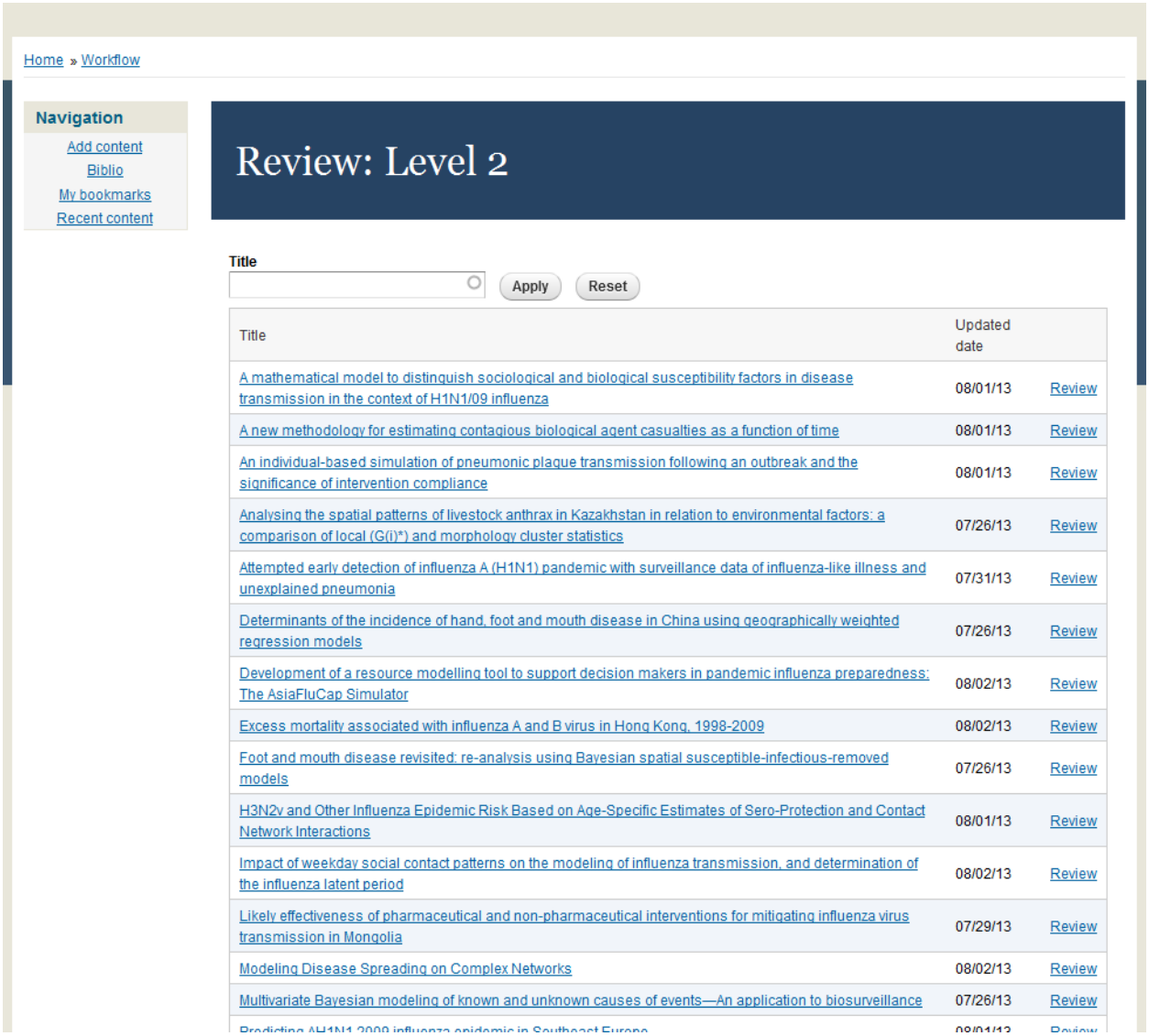
This workflow information is only accessible to those users who have been selected as editors. In addition, they are only able to see and perform review of publications in levels at or below their appointed role.

Here is shown the workflow view options in the BioCat menu for a person who is part of Level 2 review. (Note that the **Pending Review** options may appear on this menu when publications in those levels have been flagged as needing a second look.)



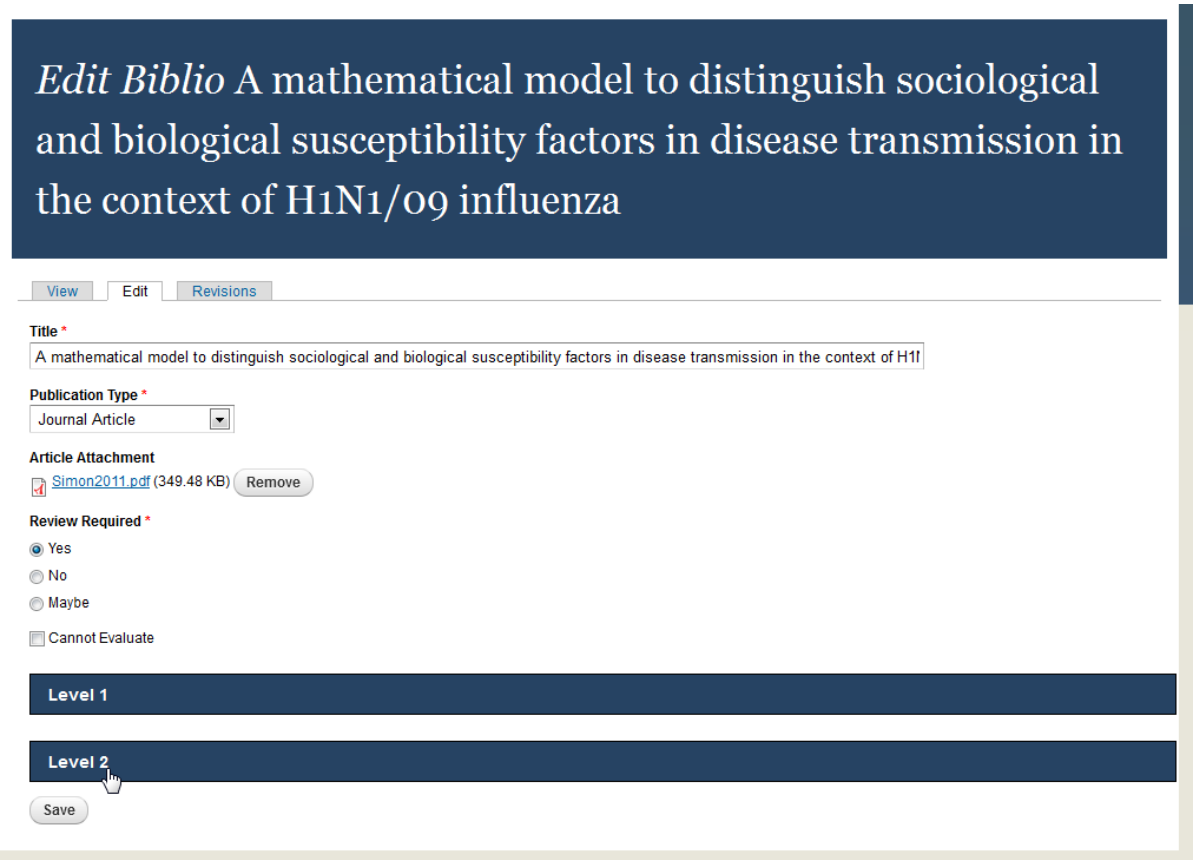

Workflow Menu Visible to Authorized Review Editors (Example)

Each of the workflow view pages on the **Workflow** menu list publications that are currently in the corresponding level of workflow. For example, the Level 2 editors can see below all the publications that are ready for them to review on the Level 2 page. They can click on the title to see the previously shown detailed view of the publication, or select **Review** to begin their review.



Workflow View Page for a Level 2 Review Editor

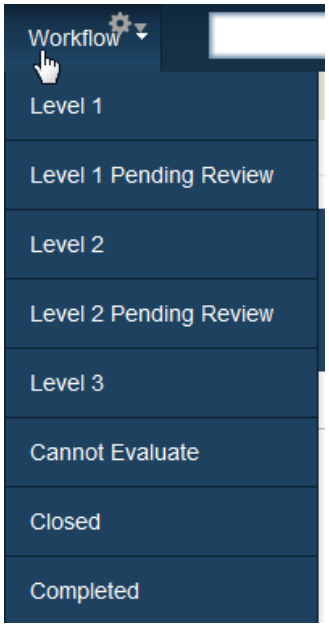
Upon selecting the **Review** option for a specific publication, users can add/change information up to their level of permission. For example, a Level 2 user can edit Level 1 data and enter Level 2 data but cannot see or edit level 3 data.



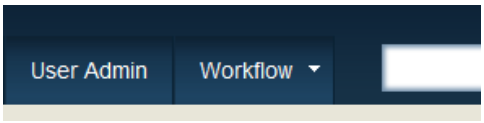

Example Form for Editing One Publication by a Level 2 Editor

The user can then save current information, flag it for a second-look review, or mark it as ready for the next level of review. Depending on the criteria previously stated, the workflow tool on the website will organize it according to its level, or take it out of the workflow process if it has been completed or closed.

Users that have been selected as BioCat administrators can see any level of the workflow and access the workflow views through the Workflow menu as shown here. They also have another option on the general menu, **User Admin**.




Workflow Menu with a Full Set of Review Options

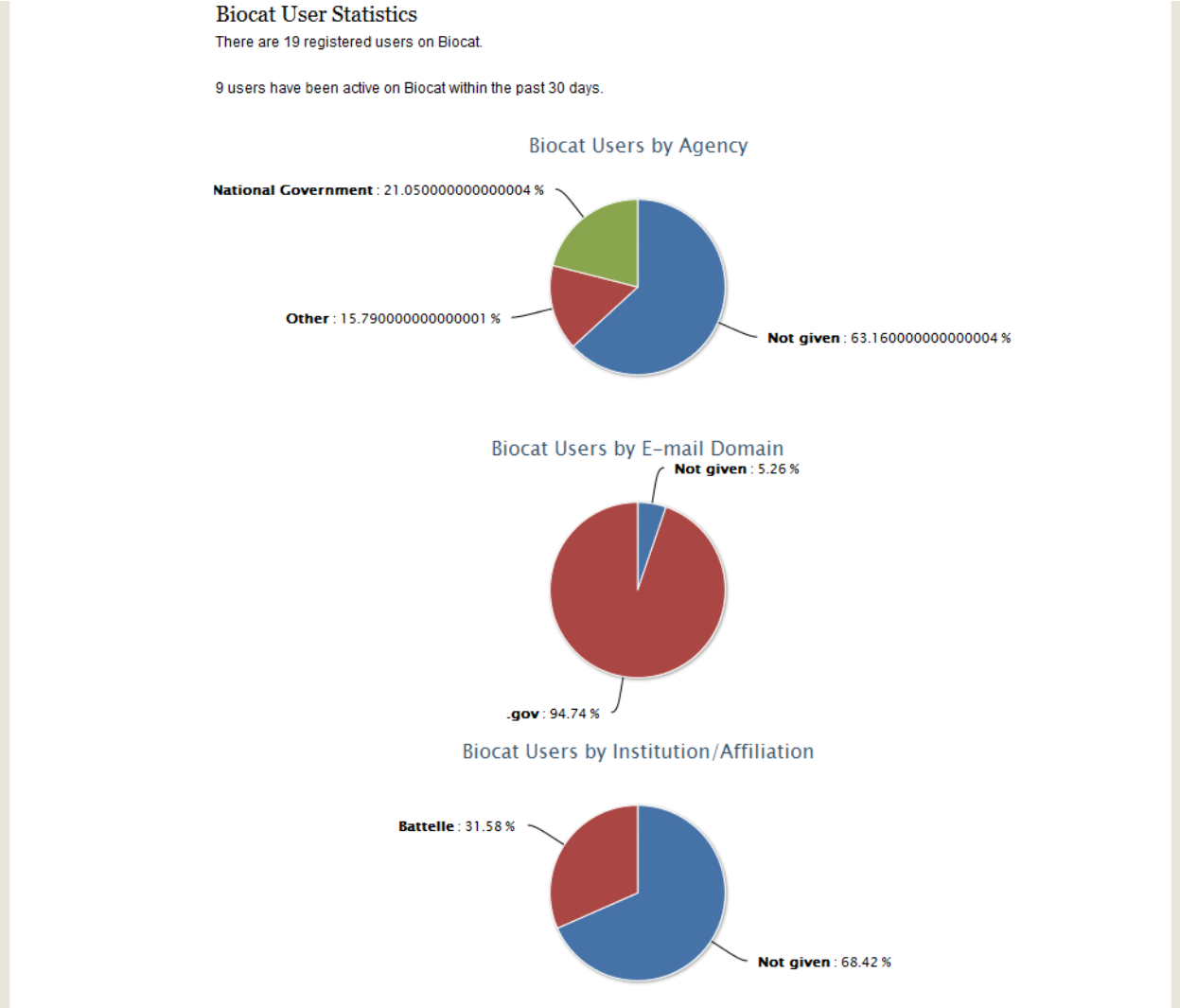



**User Admin** Option on the BioCat Menu

The user administration view page allows administrators to see a list of the users that have been registered on the site.


User Administration View Page (Example)

In addition, the user administration view page also lists statistics and charts about the users, automatically gathered by the site when users are registered.




User Statistics Charts for All the Users of the BioCat Website

# 5.0 Future Work

## 5.1 Integration of BioCat 1.0 into BioCat 2.0

Future funding efforts will enable the PNNL team to merge data collected in the first phase of research with the current work. This is a multi-step process that could be accomplished in either of two ways. The first path would consist of importing the literature citations from the first year effort into the new Drupal-based BioCat website. This can be completed relatively quickly with a small investment of funds and staffing. Literature citations would be migrated from EndNote X4 to EndNote X6 and then exported for ingestion into BioCat. The result would be that the new BioCat website would contain all the literature citations of the Phase 1 implementation, including those that may not be of confirmed interest.

The second path would be more in line with this year's efforts. The proposed first step would be to conduct a vetting process of the literature using the newly established assessment metrics, importing only those citations that survive the vetting and then evaluating a subset based on NBIC's priority list (Appendix D).

## 5.2 Enabling BioCat Accessibility on Mobile Devices

Another development direction that will likely prove useful for future use is mobile-compatible web design. Currently, the site is only made to display properly when viewed with a larger screen, such as on a desktop computer. When viewed at the smaller resolutions necessary for a tablet or phone, certain elements of the page do not display correctly, and the size of the webpage requires those with small devices to scroll left and right in addition to scrolling up and down. With additional development, the site would be adapted to automatically adjust to the width of the viewing device and to display the information in the most appropriate format according to the device being used. This would be a very helpful feature from the perspective of both users and administrators.

## 5.3 Additional Drupal Development Features

In addition to enabling mobile access, Drupal also supports additional features for development that could be useful to the BioCat user base. Examples of these features include *multilingual capabilities* and *automatic content ingestion*. Multilingual capabilities allow for the integration of more than one language into the website. This integration may be done through the navigation of the site, within the content of the site, or both. Automatic content ingestion enables Drupal to visit selected websites and social media sources, then extract content from those sources into BioCat. This could be a good way to discover new articles, refresh general site content from DHS or other agencies, or even monitor social media or other sources for mentions of topics and keywords of interest.

As time goes on, the Drupal community at large will continue to release new versions of the content manager. Ongoing maintenance of BioCat is critical to both management of day-to-day functionality and site security. The migration of BioCat into Drupal 8 (the next, developing version of Drupal) should be explored as that technology matures. This strategy will give BioCat access to significantly re-engineered features and new capabilities and it will keep the site current with the rest of the Drupal development and implementation community.

Finally, as users interact with BioCat, it is likely that additional "views" of the data will be requested to improve user work processes and to address user needs. Examples of existing views can be found on the various Workflow pages or the publications page. Examples of new views might include additional visualizations of publication information, reports, raw data for integration with other applications, or content workflow updates.

# Appendix A

# Biosurveillance Modelers and Stakeholders

The following table provides contact information and websites of the experts and research institutions that were identified as focused on the topic of biosurveillance.

| Name | Agency | Division | Email | Phone | Address | Position | Website(s) |
|---|---|---|---|---|---|---|---|
| Anderson, Sir Roy M | Imperial College London | School of Public Health | roy.anderson@imperial.ac.uk | 44 (0)20 7594 3399 | G22, Norfolk Place, St. Mary's Campus | Chair in Infectious Disease Epidemiology | |
| Anyamba, Assaf | NASA | Goddard Earth Sciences Technology Center at NASA's Goddard Space Flight Center | Assaf.Anyamba@nasa.gov | (301) 614-6601 | NASA Goddard Building 33, Room G308<br>NASA GSFC, Code 618<br>Greenbelt, MD 20771 USA | Associate Research Scientist | http://gimms.gsfc.nasa.gov/ |
| Arthur, Ray | HHS/CDC | Global Disease Detection Operations Center | rca8@cdc.gov; ray.arthur@cdc.hhs.gov | (404) 639-3855 | Atlanta, Georgia | Director | |
| Barrett, Christopher L. | Virginia Tech | Virginia Bioinformatics Institute | cbarrett@vbi.vt.edu | (540) 231-1745 | Research Building XV<br>Virginia Tech<br>Blacksburg, VA 24061 USA | Director of Network Dynamics and Simulation Science Laboratory | http://ndssl.vbi.vt.edu/people/cbarrett.html |
| Bartrand, Timothy A. | Tetra Tech Clancy Environmental Consultants, Drexel University | Environmental Information Services Group | tab32@drexel.edu; tbartrand@clancyenv.com | (610) 668-9227 | 109 Llanfair Rd<br>Bala Cynwyd, PA 19004 USA | Environmental Engineer, Visiting research assistant professor | |
| Beardsley, Kristine | FBI | Bioterrorism Prevention Program in the Weapons of Mass Destruction Directorate | kristine.beardsley@ic.fbi.gov | | | Supervisory Special Agent | |
| Beckham, Tammy | Texas A&M | Texas Veterinary Medical Diagnostic Laboratory | trbeckham@ag.tamu.edu; tbeckham@tvmdl.tamu.edu | 979-845-2855 | 1500 Research Parkway, Ste. 130<br>College Station, TX 77845 | Director of Department of Homeland Security's Center of Excellence for Foreign Animal and Zoonotic Diseases (FAZD Center) | |

Biosurveillance Modelers and Stakeholders

| Name | Agency | Division | Email | Phone | Address | Position | Website(s) |
|---|---|---|---|---|---|---|---|
| Blackburn, Jason | University of Florida | Emerging Pathogens Institute | jkblackburn@ufl.edu | 352-392-0494 | Emerging Pathogens Institute University of Florida, Gainesville, FL | | |
| Boghossian, Aida | USDA | DOD/NCMI | aboghossian@ncmi.detrick.army.mil | 301-619-8539 | Ft Detrick, Frederick, MD | USDA/APHIS rep | |
| Boots, Mike | University of Exeter, UK | Centre for Ecology and Conservation, College of Life and Environmental Sciences | m.boots@exeter.ac.uk | 44 (0) 13 2625 5735 | Daphne du Maurier Centre for Ecology and Conservation College of Life and Environmental Sciences University of Exeter, Cornwall Campus TR10 9 EZ UK | Professor of Disease Biology | http://people.exeter.ac.uk/mb437/ |
| Bright, Patti | Department of the Interior | Contaminant Biology Program | pbright@usgs.gov | 703-648-4238 | | Acting USGS Contaminant Biology Program Coordinator | |
| Buckeridge, David L. | University Clinic - Royal Victoria Hospital, Canada | Department of Epidemiology, Biostatistics and Occupational Health | david.buckeridge@mcgill.ca | 514-934-1934 Ext. 32991 | Pine 1140 1140 avenue des Pins Ouest Montreal H3A 1A3 Quebec Canada | Associate Professor | http://surveillance.mcgill.ca/index.html |
| Butel, Mike | DoD | Global Health Surveillance | Michael.Butel@ha.osd.mil | | U.S. Department of Defense Arlington, VA | NIWG Principal, Assistant Secretary of Defense (Health Affairs) | |

| Name | Agency | Division | Email | Phone | Address | Position | Website(s) |
|---|---|---|---|---|---|---|---|
| Capela, Ruben | Universidade da Madeira, Portugal | Department of Biology & Geology | rcapela@uma.pt | 351 291 705002 ext 5380 | Department of Biology & Geology, Universidade da Madeira, Campus Universitario da Penteada, 9000 Funchal, Madeira, Portugal. | Professor | |
| Carter-Foster, Nancy | U.S. Department of State | Health Affairs | FosterNC@state.gov | (202) 647-2435 | 2201 "C" Street, Northwest Washington, D.C. 20520 USA | Senior advisor | |
| Chen, Mark L. | National University of Singapore | Saw Swee Hock School of Public Health | mark_ic_chen@ttsh.com.sg | (65) 63577317 | 11 Jalan Tan Tock Seng Clinical Epidemiology Singapore 308433 | Consultant Epidemiologist | |
| Clarke, Neville | Texas A&M | Foreign Animal and Zoonotic Disease Defense | n-clarke@tamu.edu | (979) 845-2855 | | Director | http://fazd.tamu.edu/ |
| Clements, Archie C.A. | University of Queensland, Herston, QLD, Australia and Queensland Institute of Medical Research, Herston, QLD | School of Population Health and Australian Centre for International and Tropical Health | a.clements@uq.edu.au | 61-7-334-64706 | Dr. Archie C A Clements, School of Population Health, University of Queensland, Herston Road, Herston, Queensland, 4006, Australia | Associate professor, head of Infectious Disease Epidemiology Unit | |
| Codeco, Claudia T. | Oswaldo Cruz Foundation, Rio de Janeiro, Brazil | The Scientific Computing Program | codeco@malaria.procc.fiocruz.br; codeco@fiocruz.br; codeco@icict.fiocruz.br | 55-21-598-4399 | Programa de Computação Científica/ Fundação Oswaldo Cruz Av. Brasil, 4365, Manguinhos Rio de Janeiro, RJ, Brasil, 21045-900 | Associate Researcher | |
| Colwell, Rita | Johns Hopkins | Bloomberg School | rcolwell@jhsph.ed | 410-955-3720 | 615 N. Wolfe | Distinguished | |

| Name | Agency | Division | Email | Phone | Address | Position | Website(s) |
|---|---|---|---|---|---|---|---|
| | University, Canon US Life Sciences, Inc. | of Public Health, Environmental Health Sciences | u | | Street<br>Baltimore, MD 21205 | Professor, Chairman | |
| Cooke, William H. | Mississippi State University | GeoResources Institute | whc5@geosci.msstate.edu | 601-325-9479 | GeoResources Institute<br>Box 9652<br>Mississippi State, MS 39762 | Associate professor, research scientist, interim department head | |
| Corcoran, Patrick | US Postal Service | Dangerous Mail Investigations | PJCorcoran@uspis.gov | | | Inspector in Charge for Operational Support | |
| Craft, David L. | Massachusetts General Hospital and Harvard Medical School | Department of Radiation Oncology and Operations Research Center | dcraft@alum.mit.edu; dcraft@partners.org | | Massachusetts General Hospital<br>Northeast Proton Center - NPTC<br>55 Fruit St<br>Boston, MA 02114 | Assistant Professor | |
| Craigmile, Peter F. | Ohio State University, University of Glasgow, Scotland | Department of Statistics | pfc@stat.osu.edu; peter.craigmile@glasgow.ac.uk | | School of Mathematics and Statistics<br>University Gardens<br>University of Glasgow<br>Glasgow, G12 8QQ<br>United Kingdom | Associate Professor, Reader | http://www.stats.gla.ac.uk/~pcraigmile/ |
| Culotta, Aron | Northeastern Illinois University | Department of Computer Science | A-Culotta@neiu.edu | (773) 442-4720 (department) | 5500 N. St. Louis Avenue<br>Chicago, IL 60625 | Assistant Professor | http://cs.neiu.edu/~culotta |
| Daszak, Peter | EcoHealth Alliance; Columbia University | Center for Infection and Immunity | daszak@ecohealthalliance.org | 212-380-4473; 815-365-8337 | 460 West 34th St, 17th floor, New York, NY 10001-2320 | President and Disease Ecologist, adjunct professor | |
| Dowling, Glenn | DOD/NCMI | | gdowling@ncmi.detrick.army.mil | | | | |

| Name | Agency | Division | Email | Phone | Address | Position | Website(s) |
|---|---|---|---|---|---|---|---|
| Dubrawski, Artur | Carnegie Mellon University | Auton Lab | awd@cs.cmu.edu | (412) 268-6233 | Carnegie Mellon University<br>Auton Lab<br>5000 Forbes Ave<br>NSH 3121<br>Pittsburgh, PA 15213 | Director (Auton Lab), Systems Scientist (Robotics Institute), Adjunct professor (Heinz College) | http://www.autonlab.org/autonweb/10223.html |
| Eagle, Nathan | MIT; txteagle Inc., Northeastern University, The Santa Fe Institute, Harvard University | MIT Media Lab, Department of Epidemiology at Harvard; Computer Science at Northeastern | nathan@mit.edu; eagle@hsph.harvard.edu | 857-776-3279; (505) 204-6637 | MIT Design Laboratory<br>77 Massachusetts Ave<br>Bldg E15-383<br>Cambridge MA 02139<br>The Santa Fe Institute<br>1399 Hyde Park Rd<br>Santa Fe, NM 87501 | CEO of txteagle, Adjunct Assistant Professor at Harvard, visiting assistant professor at MIT Media lab, research assistant professor at Northeastern, Omidyar Fellow at Santa Fe Institute | |
| Eisen, Rebecca J. | CDC | Division of Vector Borne Infectious Diseases, National Center for Zoonotic, Vector Borne, and Enteric Diseases, Ft. Collins, Co. | dyn2@cdc.gov; rebecca.eisen@cdc.hhs.gov | (970) 266-3523 | 3150 Rampart Rd<br>Fort Collins CO 80521 | Research biologist | |
| Elderd, Bret D. | LSU | Department of Biological Sciences | elderd@lsu.edu | 225-578-6733 | 206 Life sciences Annex<br>Baton Rouge, LA 70803 | Assistant professor | |
| Engeljohn, Dan | Department of Agriculture | Office of Field Operations | daniel.engeljohn@fsis.usda.gov | 202-720-5439; 202-205-0495 | Jamie Whitten Building<br>1400 Independence Avenue, SW<br>Room 344-E<br>Washington, DC 20250-3700 | Assistant Administrator | |

| Name | Agency | Division | Email | Phone | Address | Position | Website(s) |
|---|---|---|---|---|---|---|---|
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# Appendix B

## Client-Identified Source Lists for Agents, Toxins, and Pathogens of Interest[1]

| List Name | List Location | NBIC Target Domains |
|---|---|---|
| HHS and USDA Select Agents and Toxins | http://www.selectagents.gov/resources/List_of_Select_Agents_and_Toxins_2012-12-4.pdf | Human, Animal, Plant, Food |
| CDC - The Top 5 Causes of Waterborne Outbreaks in Private Groundwater Wells | http://www.cdc.gov/healthywater/drinking/private/wells/diseases.html | Human, Environment, Food |
| EPA - Regulated Microorganisms (pathogens - excludes indicator organisms) | http://water.epa.gov/drink/contaminants/index.cfm#Microorganisms | Human, Environment, Food |
| CDC - Bioterrorism Agents/Diseases | http://www.bt.cdc.gov/agent/agentlist-category.asp | Human, Animal, Environment, Food |
| CDC - Healthcare-Associated Infections (HAIs) | http://www.cdc.gov/HAI/organisms/organisms.html | Human, Food |
| CDC - List of Nationally Notifiable Conditions | http://wwwn.cdc.gov/nndss/document/2012_Case%20Definitions.pdf | Human, Animal , Environment, Food |
| USDA - National Animal Health Reportable Disease List | http://www.aphis.usda.gov/animal_health/nahrs/downloads/2011_nahrs_dz_list.pdf | Human, Animal , Environment, Food |
| USDA - Pathogens that Threaten U.S. Agriculture | http://www.ars.usda.gov/research/docs.htm?docid=14271 | Food, Plant |
| Pests and Pathogens Threatening North American Forests, Trees | http://www.dontmovefirewood.org/ | Food, Plant |

[1] These lists were received from the client via email on December 13, 2012.

# Appendix C

# De-duplicated List of Agents, Toxins, and Pathogens of Interest

| List(s) Source | Disease or Agent Name | Synonyms, Include Disease/Agent Specified (; separated) |
|---|---|---|
| **1** | Abrin | Abrin; Abrin; abrin-a; Proteopedia 1abr; Abrin poisoning; rosary pea; jequirity pea; *Abrus precatorius* |
| **5** | *Acinetobacter* | *Acinetobacter*; *Acinetobacter baumannii* |
| **1, 7** | African horse sickness virus | African horse sickness virus; African horse sickness; AHSV; AHS |
| **1, 7** | African swine fever virus | African swine fever virus; African swine fever |
| **1** | Akabane virus | Akabane virus; Akabane disease; Tinaroo virus; Sabo virus; Yaba-7 |
| **9** | Alder Dieback | Alder Dieback; *Phytophthora alni*; alder die back |
| **8, 9** | Ambrosia beetle | Ambrosia beetle; *Xyleborus glabratus*; laurel wilt |
| **6, 7** | Anaplasmosis (*Anaplasma marginale, A. centrale*) | Anaplasmosis; *Anaplasma marginale*; *Anaplasma centrale*; gall sickness |
| **9** | Asian Gypsy Moth | Asian Gypsy Moth; *Lymantria dispar asiatica*; *Lymantria dispar japonica* |
| **9** | Asian Longhorned Beetle | Asian Longhorned Beetle; *Anoplophora glabripennis*; Asian Longhorned beetle |
| **7** | Aujeszky's Disease (Pseudorabies) | Aujeszky's Disease; Pseudorabies; PRV |
| **7** | Avian chlamydiosis (psittacosis and ornithosis, *Chlamydia psittaci*) | Avian chlamydiosis; psittacosis; ornithosis; *Chlamydia psittaci*; avian chlamydiosis |
| **7** | Avian infectious bronchitis | Avian infectious bronchitis; IB |
| **7** | Avian infectious laryngotracheitis | Avian infectious laryngotracheitis; ILT |
| **1** | Avian influenza virus | Avian influenza virus; highly pathogenic avian influenza virus; HPAI virus; HPAI A(H5N1); bird flu |
| **6, 7** | Babesiosis | Babesiosis; *Babesia bovis; Babesia bigemina; Babesia microti* |
| **1, 4, 6, 7** | *Bacillus anthracis* | *Bacillus anthracis*; anthrax; woolsorter's disease; ragpicker's disease |
| **1** | *Bacillus anthracis* Pasteur strain | *Bacillus anthracis* Pasteur strain |

| List(s) Source | Disease or Agent Name | Synonyms, Include Disease/Agent Specified (; separated) |
|---|---|---|
| **9** | Balsam Woolly Adelgid | Balsam Woolly Adelgid; *Adelges piceae* |
| **9** | Banded Elm Bark Beetle | Banded Elm Bark Beetle; *Scolytus schevyrewi* |
| **9** | Beech Bark Disease | Beech Bark Disease; *Nectria coccinea* var. faginata Lohman; beech scale |
| **1, 7** | Bluetongue virus (exotic) | Bluetongue virus exotic; bluetongue virus; BTV; catarrhal fever |
| **1, 4, 6** | Botulinum neurotoxin producing species of Clostridium* | Botulinum neurotoxin producing species of Clostridium; *Clostridium botulinum; Clostridium butyricum; Clostridium baratii; Clostridium argentinense*; botulism |
| **1, 4** | Botulinum neurotoxins | Botulinum neurotoxins; BoNT; botulinum toxin; botulinum toxin type A; botulinum toxin type B; botulinum toxin type C1; botulinum toxin type D; botulinum toxin type E; botulinum toxin type F; botulinum toxin type G; BTX-A; BTX-C1; BTX-D; BTX-E; sausage poison; fatty poison |
| **7** | Bovine Genital Campylobacteriosis (*Campylobacter fetus venerealis*) | Bovine Genital Campylobacteriosis; *Campylobacter fetus venerealis*; bovine venereal campylobacteriosis; BVC |
| **1, 7** | Bovine spongiform encephalopathy agent | Bovine spongiform encephalopathy agent; bovine spongiform encephalopathy prion; CJD prion; Bovine spongiform encephalopathy; BSE; variant Creutzfeldt–Jakob disease; CJD; v-CJD; new variant Creutzfeld-Jakob disease; nv-CJD; mad cow disease |
| **7** | Bovine Tuberculosis (*Mycobacterium bovis*) | Bovine Tuberculosis; *Mycobacterium bovis*; Bovine TB |
| **7** | Bovine viral diarrhea (BVD) | Bovine viral diarrhea; BVD; pestivirus genus; BVDV; BVDV-1; BVDV-2; hog cholera virus |
| **9** | Bromeliad Weevil | Bromeliad Weevil; *Metamasius callizona* |
| **9** | Brown Longhorned Spruce Beetle | Brown Longhorned Spruce Beetle; *Tetropium fuscum* |
| **1, 7** | *Brucella abortus* | *Brucella abortus*; bovine brucellosis; brucellosis; Bang's disease; Crimean fever; Gibraltar fever; Malta fever; Maltese fever; Mediterranean fever; rock fever; undulant fever; contagious abortion; infectious abortion |

| List(s) Source | Disease or Agent Name | Synonyms, Include Disease/Agent Specified (; separated) |
|---|---|---|
| **1, 7** | *Brucella suis* | *Brucella suis*; brucellosis; Porcine brucellosis; Enzootic Abortion; Contagious Abortion, Undulant Fever |
| **1, 4, 6, 7** | Brucellosis (*Brucella* species) | Brucellosis (*Brucella* species) |
| **1, 7** | Brucellosis, Ovine and Caprine | Brucellosis, Ovine; Brucellosis, Caprine; *Brucella melitensis; Brucella ovis*; ovine epididymitis; Malta Fever |
| **5** | *Burkholderia cepacia* | *Burkholderia cepacia* |
| **1, 4, 7** | *Burkholderia mallei** | *Burkholderia mallei; Pseudomonas mallei*; glanders |
| **1** | *Burkholderia pseudomallei** | *Burkholderia pseudomallei; Pseudomonas pseudomallei*; melioidosis; Whitemore's disease |
| **9** | Butternut Canker | Butternut Canker; *Ophiognomonia clavigignenti-juglandacearum* |
| **9** | Cactus Moth | Cactus Moth; *Cactoblastis cactorum*; Prickly pear moth |
| **1** | Camel pox virus | Camel pox virus; CMPV; Camelpox |
| **2** | *Campylobacter jejuni* | *Campylobacter jejuni*; campylobacteriosis; campy; campylobacter enteritis; gastroenteriti; *Campylobacter fetus* subsp. Jejuni |
| **8** | *Candidatus Liberibacter asiaticus, L. africanus, and L. americanus* | *Candidatus Liberibacter asiaticus; L. africanus; L. americanus;* Citrus greening disease; huanglongbing; yellow dragon disease |
| **7** | Caprine arthritis and encephalitis (CAE) | Caprine arthritis and encephalitis; CAE; CAEV; Caprine arthritis and encephalitis virus |
| **1** | Cercopithecine herpesvirus 1 (Herpes B virus) | Cercopithecine herpesvirus 1; Herpes B virus; Herpesvirus simiae; Macacine herpesvirus 1; Cercopithecine Herpesvirus 1; Herpes Simian B virus; Herpes B virus; herpes B; monkey B virus; herpesvirus simiae; herpesvirus B; CHV-1; CeHV-1; SHBV |
| **6** | Chancroid | Chancroid; *Haemophilus ducreyi* |
| **9** | Chestnut Blight | Chestnut Blight; *Cryphonectria parasitica* |
| **9** | Chestnut Gall Wasp | Chestnut Gall Wasp; *Dryocosmus kuriphilus* |
| **6** | *Chlamydia trachomatis* infection | *Chlamydia trachomatis* infection; *Chlamydia trachomatis*; chlamydia |
| **6** | Cholera | Cholera; *Vibrio cholera* |

| List(s) Source | Disease or Agent Name | Synonyms, Include Disease/Agent Specified (; separated) |
|---|---|---|
| **8** | Citrus leprosis virus | Citrus leprosis virus; Nail-head rust; nail-head spot; scaly bark |
| **9** | Citrus Longhorned Beetle | Citrus Longhorned Beetle; *Anoplophora chinensis* |
| **1, 7** | Classical swine fever virus | Classical swine fever virus; classical swine fever; hog cholera; CSFV; pig plague |
| **5** | *Clostridium difficile* | *Clostridium difficile*; CDF; C diff |
| **1, 4** | *Clostridium perfringens* epsilon toxin | *Clostridium perfringens*,epsilon toxin; *Clostridium perfringens* enteritis; Clostridium enterotoxin poisoning |
| **5** | *Clostridium sordellii* | *Clostridium sordellii* |
| **1, 6** | Coccidioides posadasii/Coccidioides immitis | Coccidioides posadasii; Coccidioides immitis; coccidioidomycosis; Valley Fever; San Joaquin Valley Fever; desert bumps; desert rheumatism; Posadas' disease |
| **9** | Common Pine Shoot Beetle | Common Pine Shoot Beetle; *Tomicus piniperda* |
| **1** | Conotoxins (Short, paralytic alpha conotoxins containing the following amino acid sequence X1CCX2PACGX3X4X5X6CX7) | Conotoxins; short paralytic alpha conotoxins; amino acid sequence X1CCX2PACGX3X4X5X6CX7; α-conotoxin; δ-conotoxin; κ-conotoxin; μ-conotoxin; ω-conotoxin; alpha conotoxin; delta conotoxin; kappa conotoxin; mu conotoxin; omega conotoxin |
| **7** | Contagious agalactia (*Mycoplasma agalactiae, M. Capricolum capricolum, M. putrefaciens, M. mycoides mycoides, M. mycoides mycoides LC*) | Contagious agalactia; *Mycoplasma agalactiae; Mycoplasma Capricolum capricolum; Mycoplasma putrefaciens; Mycoplasma mycoides mycoides; Mycoplasma mycoides mycoides LC* |
| **7** | Contagious bovine pleuropneumonia (*Mycoplasma mycoides mycoides*) | Contagious bovine pleuropneumonia; *Mycoplasma mycoides mycoides*; CBPP |
| **7** | Contagious caprine pleuropneumonia (*Mycoplasma capricolum capripneumoniae*) | Contagious caprine pleuropneumonia; *Mycoplasma capricolum capripneumoniae*; Contagious caprine pleuropneumonia; CCPP; Mycoplasma strain F38 |
| **7** | Contagious equine metritis (*Taylorella equigenitalis*) | Contagious equine metritis; *Taylorella equigenitalis*; CEM |
| **8** | Cotton leaf curl virus | Cotton leaf curl virus; cotton leaf curl; Cotton leaf curl geminivirus; CLCuV |
| **1, 4, 6, 7** | *Coxiella burnetii* | *Coxiella burnetii*; Q fever; Query fever |

| List(s) Source | Disease or Agent Name | Synonyms, Include Disease/Agent Specified (; separated) |
|---|---|---|
| **3** | coxsackieviruses A | coxsackieviruses A; Hand, foot, and mouth disease; HFMD; Cosackie A virus |
| **3** | coxsackieviruses B | coxsackieviruses B; Coxsackie B virus |
| **7** | Crayfish plague (Aphanomyces astaci) | Crayfish plague; *Aphanomyces astaci* |
| **1, 7** | Crimean-Congo hemorrhagic fever virus | Crimean-Congo hemorrhagic fever virus; Crimean-Congo hemorrhagic fever; CCHF |
| **8** | *Cronartium flaccidum* | *Cronartium flaccidum*; Scots pine blister rust; Cronartium rust; blister rust; pine-stem rust; resin canker; resin top disease; two-needle pine blister rust |
| **3, 6** | Cryptosporidiosis | Cryptosporidiosis; *Cryptosporidium enteritis*; crypto; *Cryptosporidium parvum* |
| **9** | Cycad Aulacaspis Scale | Cycad Aulacaspis Scale; *Aulacaspis yasumatsui* |
| **6** | Cyclosporiasis | Cyclosporiasis; *Cyclospora cayetanensis*; traveller's diarrhea; cyclospora |
| **7** | Cysticercosis (Cysticercus cellulosae, metacestode stage of Taenia solium) | Cysticercosis; *Cysticercus cellulosae*; metacestode stage of *Taenia solium*; pork tapeworm; cysticercosis; neurosysticercosis; opthalmic cysticercosis; subcutaneous cysticercosis |
| **6** | Dengue virus infections | Dengue virus infections; dengue virus; dengue fever; dengue hemorrhagic fever; dengue infection |
| **1** | Diacetoxyscirpenol | Diacetoxyscirpenol; 4,15-diacetoxyscirpenol |
| **6** | Diphtheria | Diphtheria; *Corynebacterium diphtheriae* |
| **9** | Dogwood Anthracnose Disease | Dogwood Anthracnose ; *Discula destructiva* |
| **7** | Dourine (*Trypanosoma equiperadum*) | Dourine; *Trypanosoma equiperadum* |
| **7** | Duck viral hepatitis | Duck viral hepatitis; duck hepatitis |
| **9** | Dutch Elm Disease | Dutch Elm Disease; *Ophiostoma ulmi; Ophiostoma himal-ulmi; Ophiostoma novo-ulmi* |
| **2** | *E. coli* 0157:H7 | *E. coli* 0157:H7; *Escherichia coli; E. coli*; Shiga toxin-producing *E. coli*; STEC; enterohemorrhagic *E. coli;* EHEC; *E. coli* gastroenteritis |
| **1** | Eastern Equine Encephalitis virus | Eastern Equine Encephalitis virus; EEEV; EEE |

| List(s) Source | Disease or Agent Name | Synonyms, Include Disease/Agent Specified (; separated) |
|---|---|---|
| **1** | Ebola virus | Ebola virus; Ebola; Ebola hemorrhagic fever; EHF; Ebola virus; EBOV; Zaire ebolavirus; ZEBOV; Sudan ebolavirus; SEBOV; Reston ebolavirus; REBOV; Cote d'Ivoire ebolavirus; CIEBOV; Bundibugyo ebolavirus |
| **7** | Echinococcosis / hydatidosis | Echinococcosis; hydatidosis; *Echinococcosis granulosus; Echinococcosis multilocularis; Echinococcosis oligarthrus; Echinococcosis vogeli; Echinococcosis shiquicus*; hydatid disease; cycstic echinococcosis |
| **3** | echoviruses | echoviruses; Enteric Cytopathic Human Orphan virus |
| **1** | Ehrlichia ruminantium (Heartwater) | *Ehrlichia ruminantium*; Heartwater; *Cowdria ruminatum;* cowdriosis |
| **6** | Ehrlichiosis | Ehrlichiosis; Human monocytic ehrlichiosis; HME; Human granulocytic ehrlichiosis; HGE; Human granulocytic anaplasmosis; HGA |
| **9** | Emerald Ash Borer | Emerald Ash Borer; *Agrilus planipennis* |
| **5** | *Enterobacteriaceae* (carbapenem-resistant) | *Enterobacteriaceae;* carbapenem-resistant; gram negative bacteria |
| **3** | enteroviruses | enteroviruses |
| **7** | Enzootic abortion of ewes (Ovine psittacosis, *Chlamydia psittaci*) | Enzootic abortion of ewes; Ovine psittacosis; *Chlamydia psittaci*; Enzootic abortion of ewes |
| **7** | Enzootic bovine leukosis (BLV) | Enzootic bovine leukosis; BLV |
| **7** | Epizootic hematopoietic necrosis | Epizootic hematopoietic necrosis; EHN; EHNV |
| **7** | Epizootic hemorrhagic disease (EHD) | Epizootic hemorrhagic disease; EHD |
| **7** | Epizootic ulcerative syndrome | Epizootic ulcerative syndrome; EUS |
| **7** | Equine herpesvirus myeloencephalopathy (EHV1 - EHM) | Equine herpesvirus myeloencephalopathy; EHV1; EHV1-EHM |
| **7** | Equine infectious anemia | Equine infectious anemia; EIA; EIAV |
| **7** | Equine influenza (Virus Type A) | Equine influenza (Virus Type A); horse flu |
| **7** | Equine piroplasmosis (Babesiosis, *Babesia [Piroplasma] equi, B. caballi)* | Equine piroplasmosis (Babesiosis, *Babesia [Piroplasma] equi, Babesia caballi*); Equine piroplasmosis; EP |

| List(s) Source | Disease or Agent Name | Synonyms, Include Disease/Agent Specified (; separated) |
|---|---|---|
| **7** | Equine rhinopneumonitis (EHV 1 and 4) | Equine rhinopneumonitis; Equine viral rhinopneumonitis; EHV1; EHV4; Equine abortion virus |
| **7** | Equine viral arteritis (EVA) | Equine viral arteritis; EVA |
| **9** | Erythrina Gall Wasp | Erythrina Gall Wasp; *Quadrastichus erythrinae* |
| **9** | Eurasian Nun Moth | Eurasian Nun Moth; *Lymantria monacha* |
| **9** | European Gypsy Moth | European Gypsy Moth; *Lymantria dispar*; EGM |
| **9** | European Larch Canker | European Larch Canker; *Lachnellula (Dasyscypha) willkommii* (Hartig) |
| **9** | European Oak Bark Beetle | European Oak Bark Beetle; *Scolytus intricatus* |
| **9** | European Spruce Bark Beetle | European Spruce Bark Beetle; *Ips typographus* L. |
| **1, 7** | Foot and mouth disease virus | Foot-and-mouth disease virus; *Aphtae epizooticae*; FMDV; FMD; FMD serotype |
| **7** | Fowl cholera (*Pasteurella multocida*) | Fowl cholera; *Pasteurella multocida*; Pasteurellosis |
| **7** | Fowl typhoid (*Salmonella gallinarum*) | Fowl typhoid; *Salmonella gallinarum* |
| **1, 4, 6, 7** | *Francisella tularensis** | *Francisella tularensis*; tularemia; Pahvant Valley plague; rabbit fever; deer fly fever; Ohara's fever |
| **9** | Pine Pitch Canker | Pine Pitch Canker; *Fusarium circinatum* |
| **9** | *Fusarium* fungus, unnamed | *Fusarium* fungus; *Fusarium* spp. |
| **8** | *Geosmithia* sp. | *Geosmithia* sp.; Thousand cankers disease; *Geosmithia morbida* |
| **2, 3, 6** | *Giardia* | *Giardia*; *Giardia intestinalis; Giardia lamblia; Giardia duodenali*; Giardiasis |
| **1, 7** | Goat pox virus | Goat pox virus; goatpox; goat pox; *Variola caprina* |
| **9** | Golden Haired Pine Bark Beetle | Golden Haired Pine Bark Beetle; *Hylurgus ligniperda*; Golden-haired bark beetle |
| **9** | Goldspotted oak borer | Goldspotted oak borer; *Agrilus auroguttatus*; GSOB |
| **6** | Gonorrhea | Gonorrhea; the clap; *Neisseria gonorrhoeae* |
| **7** | Gyrodactylosis | Gyrodactylosis; *Gyrodactylus salaris* |
| **6** | *Haemophilus influenzae*, invasive disease | Haemophilus influenza; invasive disease; *Haemophilus influenzae* type B; Hib; Pfeiffer's bacillus; *Bacillus influenzae* |

| List(s) Source | Disease or Agent Name | Synonyms, Include Disease/Agent Specified (; separated) |
|---|---|---|
| **6** | Hansen's disease (leprosy) | Hansen's disease; leprosy |
| **4, 6** | Hantavirus pulmonary syndrome | *Hantavirus* pulmonary syndrome; *Hantavirus*; HPS |
| **8** | *Harpophora maydis* | *Harpophora maydis*; late wilt of maize |
| **9** | Harrisia cactus mealybug | Harrisia cactus mealybug; *Hypogeococcus pungens* |
| **7** | Heartwater (*Cowdria ruminantium*) | Heartwater; *Cowdria ruminantium; Cowdria ruminatum; Ehrlichia ruminantium*; Cowdriosis; nintas; ehrlichiosis |
| **9** | Hemlock Woolly Adelgid | Hemlock Woolly Adelgid; *Adelges tsugae* |
| **6** | Hemolytic uremic syndrome, post-diarrheal | Hemolytic uremic syndrome, post-diarrheal; Hemolytic uremic syndrome; HUS |
| **7** | Hemorrhagic septicemia (Pasteurella multocida, serotypes B/Asian or E/African) | Hemorrhagic septicemia; *Pasteurella multocida* serotype B/Asian; *Pasteurella multocida* serotype E/African; Shipping Fever; *Pasteurella multocida*; HS |
| **1** | Hendra virus | Hendra virus; Equine Morbilivirus; *Henipavirus*; HeV |
| **2, 6** | Hepatitis A | Hepatitis A; HAV; hep A |
| **5, 6** | Hepatitis B (acute, chronic or perinatal) | Hepatitis B; HBV; hep B |
| **5, 6** | Hepatitis C | Hepatitis C; HCV; hep C |
| **8** | *Heterodera* spp. and *Meloidogyne* spp. | *Heterodera* spp.; *Meloidogyne* spp.; cyst and root-knot nematodes |
| **7** | Highly pathogenic avian influenza | Highly pathogenic avian influenza; HPAI |
| **5, 6** | Human Immunodeficiency Virus (HIV) | Human Immunodeficiency Virus; HIV; AIDS |
| **7** | Infection with abalone herpes-like virus | Infection with abalone herpes-like virus; AbHV; abalone viral ganglioneuritis; AVG |
| **7** | Infection with *Bonamia exitiosa* | *Bonamia exitiosa* |
| **7** | Infection with *Bonamia ostreae* | *Bonamia ostreae*; bonamiosis |
| **7** | Infection with *Marteilia refringens* | *Marteilia refringens*; Aber disease; marteiliosis |
| **7** | Infection with *Perkinsus marinus* | *Perkinsus marinus*; Dermo; Perkinsosis |
| **7** | Infection with *Perkinsus olseni* | *Perkinsus olseni*; *Perkinsus atlanticus* |
| **7** | Infection with *Xenohaliotis californiensis* | *Xenohaliotis californiensis;* withering syndrome; abalone rickettsiosis |

| List(s) Source | Disease or Agent Name | Synonyms, Include Disease/Agent Specified (; separated) |
|---|---|---|
| **7** | Infectious bovine rhinotracheitis/infectious pustular vulvovaginitis (IBR/IPV) | Infectious bovine rhinotracheitis/infectious pustular vulvovaginitis; IBR/IPV; Bovine herpesvirus 1; bovine rhinotracheitis; infectious pustular vulvovaginitis |
| **7** | Infectious bursal disease (Gumboro disease) | Infectious bursal disease; Gumboro disease; IMB; IBDV |
| **7** | Infectious hematopoietic necrosis | Infectious hematopoietic necrosis; IHN; Infectious hematopoietic necrosis virus; IHNV |
| **7** | Infectious hypodermal and haematopoietic necrosis | Infectious hypodermal and haematopoietic necrosis; IHHN; Infectious hypodermal and haematopoietic necrosis virus; IHHNV |
| **7** | Infectious myonecrosis | Infectious myonecrosis; IMN; IMNV; Infectious myonecrosis virus |
| **7** | Infectious salmon anemia | Infectious salmon anemia; ISA; ISAV; European genotype (genotype I); North American genotype (genotype II) |
| **5** | Influenza | Influenza; flu; H1N1; H3N2; Influenza A; Influenza B; Influenza C |
| **6** | Influenza-associated mortality, pediatric | Influenza-associated mortality, pediatric |
| **1, 7** | Japanese encephalitis virus | Japanese encephalitis virus; JEV; Japanese encephalitis; JE |
| **5** | *Klebsiella* | Klebsiella; *Klebsiella pneumoniae* |
| **7** | Koi herpesvirus disease | Koi herpesvirus disease; Koi herpes virus; KHV; cyprinid herpesvirus-3; CyHV-3 |
| **9** | Larch Casebearer | Larch Casebearer; *Coleophora laricella* |
| **9** | Larger Pine Shoot Beetle | Larger Pine Shoot Beetlecommon pine shoot beetle; *Tomicus piniperda* |
| **1** | Lassa fever virus | Lassa fever virus; Lassa fever; Lassa viral hemorrhagic fever |
| **8, 9** | Laurel wilt | Laurel wilt; *Raffaelea lauricola*; Laurel wilt of avocado; Laurel wilt of redbay |
| **6** | Lead, exposure screening test result | Lead, exposure screening test result |
| **3, 6** | Legionellosis / *Legionella* | Legionellosis; Legionella; *Legionella pneumophila*; Legionnaire's disease; Pontiac fever |

| List(s) Source | Disease or Agent Name | Synonyms, Include Disease/Agent Specified (; separated) |
|---|---|---|
| **7** | Leptospirosis | Leptospirosis; *Leptospira*; Weil disease; Icterohemorrhagic fever; Swineherd's disease; Rice-field fever; Cane-cutter fever; Swamp fever; Mud fever; Hemorrhagic jaundice; Stuttgart disease; Canicola fever |
| **6** | Listeriosis | Listeriosis; *Listeria monocytogenes* |
| **9** | Lobate Lac Scale | Lobate Lac Scale; *Paratachardina pseudolobata* |
| **7** | Low pathogenic avian influenza (H5 or H7 subtypes) | Low pathogenic avian influenza; Avian influenza H5; Avian influenza H7; LPAI |
| **1** | Lujo virus | Lujo virus; Lujo hemorrhagic fever; Lujo fever |
| **1, 7** | Lumpy skin disease virus | Lumpy skin disease virus; Lumpy skin disease; LSDV |
| **6** | Lyme disease | Lyme disease; *Borrelia burgdorferi* |
| **7** | Maedi-visna / ovine progressive pneumonia | Maedi-visna/ovine progressive pneumonia; ovine progressive pneumonia; progressive pneumonia; Maedi; Zwoegersiekte; La bouhite; Graaff-Reinet disease; Marsh's progressive pneumonia |
| **8** | *Magnaporthe grisea* | *Magnaporthe grisea;* Wheat blast; rice blast; rice rotten neck; rice seedling blight; blast of rice; oval leaf spot of graminea; pitting disease; ryegrass blast; Johnson spot; blast disease, blight disease |
| **6** | Malaria | Malaria; *Plasmodium falciparum; Plasmodium vivax; Plasmodium malariae; Plasmodium ovale; Plasmodium knowlesi* |
| **1, 7** | Malignant catarrhal fever virus (Alcelaphine herpesvirus type 1) | Malignant catarrhal fever virus (Alcelaphine herpesvirus type 1); Malignant catarrhal fever virus; Alcelaphine herpes virus 1; AIHV-1; Ovine herpes virus 2; OHV-2; malignant catarrhal fever; bovine malignant catarrhal fever; BMCF |
| **1** | Marburg virus | Marburg virus; Lake Victoria Marburg virus; Marburg hemorrhagic fever; MHF |
| **7** | Marek's Disease | Marek's Disease; Gallid herpesvirus 2; GaHV-2; Marek's disease virus; MDV |
| **6** | Measles | Measles; measles virus |
| **9** | Mediterranean Pine Engraver Beetle | Mediterranean Pine Engraver Beetle; *Orthotomicus erosus* |

| List(s) Source | Disease or Agent Name | Synonyms, Include Disease/Agent Specified (; separated) |
|---|---|---|
| **4** | Melioidosis | Melioidosis; *Burkholderia pseudomallei; Pseudomonas pseudomallei* |
| **1** | Menangle virus | Menangle virus |
| **6** | Meningococcal disease (*Neisseria meningitides)* | Meningococcal disease; *Neisseria meningitides*; bacterial meningitis; meningococcemia |
| **5** | Methicillin-resistant *Staphylococcus aureus* | Methicillin-resistant *Staphylococcus aureus*; *Staphylococcus aureus*; MRSA |
| **1** | Monkeypox virus | Monkeypox virus; monkeypox |
| **6** | Mumps | Mumps; mumps virus; epidemic parotitis |
| **5** | *Mycobacterium abscessus* | *Mycobacterium abscessus* |
| **1** | *Mycoplasma capricolum* | *Mycoplasma capricolum; Mycoplasma capricolum* subspecies *capripneumoniae*; contagious caprine pleuropneumonia, mastitis and severe arthritis |
| **1** | *Mycoplasma mycoides* | *Mycoplasma mycoides* |
| **1** | *Mycoplasma mycoides* subspecies *mycoides* small colony (*Mmm* SC) (contagious bovine pleuropneumonia) | *Mycoplasma mycoides* subspecies *mycoides* small colony (*Mmm* SC) (contagious bovine pleuropneumonia); contagious bovine pleuropneumonia |
| **7** | Mycoplasmosis (*M. gallisepticum*) | Mycoplasmosis; *Mycoplasma gallisepticum*; mycoplasmosis |
| **7** | Mycoplasmosis (*M. synovia*e) | Mycoplasmosis; *Mycoplasma synoviae*; mycoplasmosis |
| **7** | Nairobi sheep disease | Nairobi sheep disease; Nairobi sheep disease virus; NSDV |
| **7** | Necrotizing hepatopancreatitis | Necrotizing hepatopancreatitis; Necrotising hepatopancreatitis; NHP; Texas pond mortality syndrome; TPMS; Texas necrotizing hepatopancreatitis; TNHP; Peru necrotizing hepatopancreatitis; PNHP |
| **1, 7** | Newcastle disease virus | Newcastle disease virus; Virulent Newcastle disease virus 1; Newcastle disease virus; NDV; Newcastle disease; velogenic Newcastle disease; mesogenic Newcastle disease |

| List(s) Source | Disease or Agent Name | Synonyms, Include Disease/Agent Specified (; separated) |
|---|---|---|
| **1, 4, 7** | Nipah virus | Nipah virus; Nipah virus encephalitis |
| **5** | Norovirus | Norovirus; stomach flu; winter vomiting bug; Norwalk-like virus |
| **6** | Novel Influenza A virus infection | Novel Influenza A virus infection; influenza |
| **9** | Oak Dieback | Oak Dieback; *Phytophtora quercina* |
| **9** | Ohi'a Rust | Ohi'a Rust; *Puccinia psidii* Winter; *Puccinia* rust |
| **7** | Paratuberculosis | Paratuberculosis; *Mycobacterium avium* paratuberculosis; MAP; Johne's disease |
| **1, 8** | *Peronosclerospora philippinensis (Peronosclerospora sacchari)* | *Peronosclerospora philippinensis; Peronosclerospora sacchari*; Phillipine downy mildew; Philippine downy mildew of maize; PDM; Brown Stripe downy mildew of corn |
| **6** | Pertussis | Pertussis; *Bordetella pertussis*; *Bordetella parapertussis*; Whooping cough |
| **1, 7** | Peste des petits ruminants | Peste des petits ruminants; Peste des petits ruminants virus; PPR; ovine rinderpest; PPRV |
| **1, 8** | *Phoma glycinicola (*formerly *Pyrenochaeta glycines)* | *Phoma glycinicola*; Red leaf blotch of soybean; *Pyrenochaeta* leaf spot; *Dactuliophora* leaf spot; *Pyrenochaeta* leaf blotch; RLB; *Pyrenochaeta glycines*; *Dactuliophora glycines; Dactuliochaeata glycines* of soybean |
| **8, 9** | *Phytophthora kernoviae* | *Phytophthora kernoviae*; Ramorum dieback; sudden oak death |
| **9** | *Phytophthora* Root Rot | *Phytophthora* Root Rot; *Phytophthora cinnamomi* |
| **9** | Pine Flat Bug | Pine Flat Bug; *Aradus cinnamomeus* Panzer |
| **8** | plum pox virus (PPV) | plum pox virus; PPV; plum pox; Sharka; Sharka virus |
| **3, 6** | Poliovirus infection | Poliovirus infection; polio; poliomyelitis; paralytic poliomyelitis; poliovirus; PV |
| **9** | Polyphagous shot hole borer | Polyphagous shot hole borer; *Euwallacea* sp.; *Fusarium* fungus |

| List(s) Source | Disease or Agent Name | Synonyms, Include Disease/Agent Specified (; separated) |
|---|---|---|
| **7** | Porcine reproductive and respiratory syndrome (PRRSV) | Porcine reproductive and respiratory syndrome (PRRSV); PRRS virus; PRRSV; porcine arterivirus; Blue ear pig disease; mystery swine disease |
| **9** | Port-Orford-Cedar Root Disease | Port-Orford-Cedar Root Disease; *Phytophthora lateralis* |
| **4, 6** | Psittacosis | Psittacosis; *Chlamydia psittaci*; parrot fever |
| **8** | *Puccinia graminis* f. sp. *tritici* | *Puccinia graminis* f. sp. *tritici*; Stem rust of wheat (Ug99); black rust |
| **7** | Pullorum disease (*Salmonella pullorum*) | Pullorum disease; Bacillary White Diarrhoea; Pullorum disease; *Salmonella pullorum*; Salmonella |
| **6, 7** | Rabies | Rabies; Rabies virus; Lyssavirus; Ephemerovirus; Vesiculovirus; Australian bat virus; Mokola virus; Duvenhage virus; European bat virus 1; European bat virus 2; Lagos bat virus |
| **1, 8** | *Ralstonia solanacearum* race 3, biovar 2 | *Ralstonia solanacearum* race 3, biovar 2; *Ralstonia* bacterial wilt of potato; *Ralstonia* bacterial wilt of tomato; *Ralstonia* bacterial wilt of geranium; Brown rot (potato); southern bacterial wilt (tomato); Moko disease (banana); Granville wilt (tobacco); Southern Wilt of Geranium |
| **1, 8** | *Rathayibacter toxicus* | *Rathayibacter toxicus*; *Clavibacter toxicus; Rathayibacter* poisoning; Annual ryegrass toxicity; ARGT; Yellow slime disease; Rathay's disease; annual ryegrass toxicosis; annual ryegrass staggers; parasitized annual ryegrass; ryegrass toxicity; toxic annual ryegrass; tunicamycin poisoning; wimmera ryegrass toxicity; Black Springs syndrome; flood plain staggers; blown grass/beard grass poisoning; corynetoxin poisoning; corynetoxicosis; Stewarts range syndrome; tunicaminyluracil toxicosis; veldtgrass staggers; bacterial galls; seed gall nematode |
| **1** | Reconstructed replication competent forms of the 1918 pandemic influenza virus containing any portion of the coding regions of all eight gene segments (Reconstructed1918 Influenza virus) | Reconstructed replication competent forms of the 1918 pandemic influenza virus containing any portion of the coding regions of all eight gene segments (Reconstructed1918 Influenza virus); 1918-like HINI; Spanish Flu; 1918 influenza; reconstructed 1918 influenza virus |

| List(s) Source | Disease or Agent Name | Synonyms, Include Disease/Agent Specified (; separated) |
|---|---|---|
| **7** | Red sea bream iridoviral disease (RSIVD) | Red sea bream iridoviral disease; RSIVD; Red sea beam iridovirus |
| **9** | Red-Haired Pine Bark Beetle | Red-Haired Pine Bark Beetle; *Hylurgus ligniperda Fabricius* |
| **1, 4** | Ricin | Ricin; Castor bean; *Ricinus communis* |
| **1, 6** | Rickettsiosis, spotted fever | Rickettsiosis, spotted fever; *Rickettsia rickettsii; Rickettsia australis; Rickettsia ; Rickettsia honei; Rickettsia japonica; Rickettsia felis*; Rickettsial spotted fever; Rocky mountain spotted fever; RMSF; Australian tick typhus; Tobia fever; Sao Paulo fever; North Asian tick typhus; Flinders Island spotted fever; Japanese spotted fever |
| **1, 7** | Rift Valley fever virus | Rift Valley fever virus; Rift Valley fever; RVF |
| **1, 7** | Rinderpest virus | Rinderpest virus; Rinderpest; cattle plague; steppe murrain; RPV |
| **6** | Rubella | Rubella; Rubella virus; German measles; congenital rubella syndrome |
| **2** | *Salmonella* serotype *Typhimurium* | *Salmonella* serotype *Typhimurium*; *Salmonella Typhimurium*; Salmonellosis |
| **6** | Salmonellosis | Salmonellosis; *Salmonella* spp; *Salmonella enterica* |
| **7** | Salmonellosis (*Salmonella abortus ovis*) | Salmonellosis (*Salmonella abortus ovis*); *Salmonella abortus* |
| **1, 6** | SARS-associated coronavirus | SARS-associated coronavirus (SARS-CoV); SARS-associated coronavirus; SARS virus; SARS-CoV; SARS; Severe Acute Respiratory Syndrome |
| **1** | Saxitoxin | Saxitoxin; saxitoxin; STX; neosaxitoxin; neoSTX; gonyautoxins; GTX; decarbamoylsaxitoxin; dcSTX; paralytic shellfish poison; PSP |
| **1, 8** | *Sclerophthora rayssiae* var *zeae* | *Sclerophthora rayssiae* var *zeae*; Brown stripe downy mildew; brown stripe downy mildew of maize; brown stripe downy mildew of corn |
| **7** | Scrapie | Scrapie; Scrapie prion |
| **7** | Screw worm, New World | Screw worm, New World; *Cochliomyia hominivorax*; New World screw worm fly; screw worm; myiasis |
| **7** | Screw worm, Old world | Screw worm, Old world; *Chrysomia bezziana*; screw worm; myiasis |

| List(s) Source | Disease or Agent Name | Synonyms, Include Disease/Agent Specified (; separated) |
|---|---|---|
| **1, 7** | Sheep pox virus | Sheep pox virus; Sheeppox virus; variola ovina; sheeppox; sheep pox |
| **1** | Shigatoxin | Shigatoxin; Stx; *Shiga*-like ribosome inactivating proteins; SLT-1; SLT-2; Stx-1; Stx-2 |
| **1, 2, 4, 6** | Shigellosis | Shigellosis; *Shigella* spp.; *Shigella flexneri; Shigella dysenteriae; Shigella boydii; Shigella sonne*i; bacillary dystentery; Marlow syndrome |
| **9** | Sirex Woodwasp | Sirex Woodwasp; *Sirex noctilio* |
| **9** | Soapberry Borer | Soapberry Borer; *Agrilus prionurus* |
| **7** | Spring viremia of carp | Spring viremia of carp; spring viremia of carp virus; SVCV; Infectious Dropsy of Carp; Infectious Ascites; Hydrops; Red Contagious Disease; Rubella; Hemorrhagic Septicemia |
| **9** | Spruce Aphid | Spruce Aphid; *Elatobium abietinum* |
| **1, 4** | Staphylococcal enterotoxins | Staphylococcal enterotoxins; *Staphylococcus aureus* enterotoxin; Staphylococcal enterotoxins; Staphylococcal enterotoxin B; SEB; Staphylococcal enterotoxins A,B,C,D,E subtypes; staphyloenterotoxicosis; staphyloenterotoxemia; staphylococcal food poisoning |
| **5, 6** | *Staphylococcus aureus* infection | *Staphylococcus aureus* infection; staph; *staph aureus*; *Staphylococcus aureus* |
| **6** | Streptococcal toxic shock syndrome | Streptococcal toxic shock syndrome (STSS); streptococcal toxic shock syndrome; STSS; toxic shock-like syndrome; TSLS |
| **6** | Streptococcus pneumonia, invasive disease | *Streptococcus* pneumonia, invasive disease (IPD); *Streptococcus pneumonie* |
| **9** | Sudden Oak Death Syndrome | Sudden Oak Death Syndrome; *Phytophthora ramorum* |
| **1, 7** | Swine vesicular disease | Swine vesicular disease; Swine vesicular disease virus; SVD |
| **1, 8** | *Synchytrium endobioticum* | *Synchytrium endobioticum*; Potato wart disease; black scab |
| **6** | Syphilis | Syphilis; *Treponema pallidum* subspecies *pallidum*; chancre |

| List(s) Source | Disease or Agent Name | Synonyms, Include Disease/Agent Specified (; separated) |
|---|---|---|
| **1** | T-2 toxin | T-2 toxin; alimentary toxic aleukia; fusariotoxin T2; insariotoxin; mycotoxin T-2; NSC 138780; T-2 mycotoxin |
| **7** | Taura syndrome | Taura syndrome; Taura syndrome virus; TSV |
| **6** | Tetanus | Tetanus; *Clostridium tetani*; lockjaw |
| **1** | Tetrodotoxin | Tetrodotoxin; Tetrodotoxin; tetrodox; TTX; anhydrotetrodotoxin; 4-epitetrodotoxin; tetrodonic acid; pufferfish poisoning |
| **7** | Theileriasis (*Theileria annulata, T. parva*) | Theileriasis; *Theileria annulata; Theileria parva;* theileriasis; theileria |
| **9** | Thousand Canker Disease | Thousand Canker Disease; *Geosmithia morbida* |
| **6** | Toxic shock syndrome (non-Strep) | Toxic shock syndrome (non-Strep); toxic shock syndrome; TSS |
| **7** | Transmissible gastroenteritis | Transmissible gastroenteritis; Transmissible gastroenteritis virus; TGEV; transmissible gastroenteritis; TGE |
| **6, 7** | Trichinellosis | Trichinellosis; *Trichinela spiralis* |
| **7** | *Tritrichomonas foetus* | *Tritrichomonas foetus* |
| **7** | Trypanosomiasis | Trypanosomiasis; *Trypanosoma congolense, Trypanosoma vivax; Trypanosomabrucei brucei; Trypanosoma evansi*; Surra |
| **5, 6** | Tuberculosis | Tuberculosis; TB; *Mycobacterium tuberculosis; Mycobacterium avium; Mycobacterium bovis*; consumption |
| **7** | Turkey rhinotracheitis | Turkey rhinotracheitis; avian metapneumovirus; aMPV |
| **6** | Typhoid Fever | Typhoid Fever; *Salmonella typhi*; gastric fever; abdominal typhus; infantile remittant fever; slow fever; nervous fever; pythogenic fever |
| **1, 4** | Typhus fever (*Rickettsia prowazekii*) | Typhus fever; *Rickettsia prowazekii*; typhus; epidemic typhus; camp fever; jail fever; hospital fever; ship fever; famine fever; putrid fever; petechial fever; epidemic louse-borne typhus; louse-borne typhus |
| **5** | Vancomycin-intermediate *Staphylococcus aureus* | Vancomycin-intermediate *Staphylococcus aureus; Staphylococcus aureus*; VISA |
| **5** | Vancomycin-resistant *Enterococci* | Vancomycin-resistant *Enterococci*; *Enterococci* spp; VRE |

| List(s) Source | Disease or Agent Name | Synonyms, Include Disease/Agent Specified (; separated) |
|---|---|---|
| **5** | Vancomycin-resistant *Staphylococcus aureus* | Vancomycin-resistant *Staphylococcus aureus*; *Staphylococcus aureus*; VRSA |
| **6** | Varicella | Varicella; *Varicella zoster*; Chicken pox virus; varicella zoster virus; zoster virus; human herpes virus type 3; chickenpox |
| **1, 4, 6** | Variola major virus (Smallpox virus) | Variola major virus (Smallpox virus); smallpox; *Variola major*; Variola virus; VAR; Variola vera |
| **1** | Variola minor virus (Alastrim | Variola minor virus (Alastrim); *Variola alastrim*; *Variola minor*; alastrim; white pox; kaffir pox; Cuban itch; West Indian pox; milk pox; pseudovariola |
| **1** | Venezuelan Equine Encephalitis virus | Venezuelan Equine Encephalitis virus; Venezuelan equine encephalitis; VEE; Venezuelan equine encephalomyelitis virus |
| **1, 7** | Vesicular stomatitis virus (exotic): Indiana subtypes VSV-IN2, VSV-IN3 | Vesicular stomatitis virus (exotic): Indiana subtypes VSV-IN2, VSV-IN3; Vesicular stomatitis; Vesicular stomatitis virus; VSV; Indiana subtype VSV-IN2; Indiana subtype VSV-IN3; vesicular stomatitis Indiana virus; VSIV |
| **6** | Vibriosis | Vibriosis; *Vibrio vulnificus; Vibrio parahaemolyticus* |
| **9** | Viburnum leaf beetle | Viburnum leaf beetle; *Pyrrhalta viburni* |
| **7** | Viral hemorrhagic septicemia | Viral hemorrhagic septicemia (VHS); Viral hemorrhagic septicemia virus; VHSV; Viral hemorrhagic septicemia; VHS |
| **9** | Walnut Twig Beetle | Walnut Twig Beetle; *Pityophthorus juglandis*; Thousand Cankers disease |
| **9** | White Pine Blister Rust | White Pine Blister Rust; *Cronartium ribicola* |
| **7** | White spot disease | White spot disease; *Ichthyophthirius multifiliis;* Ich; Ick |
| **7** | White tail disease | White tail disease; *Macrobrachium rosenbergii* Nodavirus; MrNV; extra small virus; XSV |
| **1, 8** | *Xanthomonas oryzae* pv. *oryzae* and *X. oryzae* pv. *oryzicola* | *Xanthomonas oryzae* pv. *oryzae* and *X. oryzae* pv. *Oryzicola*; *Xanthomonas oryzae*; Rice blight disease; Bacterial leaf blight; BLB; Kresek disease; Bacterial leaf streak; BLS |

| List(s) Source | Disease or Agent Name | Synonyms, Include Disease/Agent Specified (; separated) |
|---|---|---|
| **1, 8** | *Xylella fastidiosa* (citrus variegated chlorosis strain) | *Xylella fastidiosa* (citrus variegated chlorosis strain); Pierce's disease; California vine disease; Anaheim disease (grapevine); leaf scorch (almond); dwarf (lucerne); phony disease (peach); leaf scald (plum); leaf scorch (elm, oak, plane, mulberry, maple); variegated chlorosis (citrus) |
| **6** | Yellow Fever | Yellow Fever; Yellow fever virus; Yellow Jack; Bronze John |
| **7** | Yellowhead disease | Yellowhead disease; Yellowhead virus |
| **1, 4, 6** | *Yersinia pestis* | *Yersinia pestis*; Plague bacteria; Plague; bubonic plague; pneumonic plague; Black Death |

# Appendix D

# Prioritized List of Agents for BioCat[1]

The recommendation for a prioritized list of biological agents is shown in the table below. The list is based on the Tier 1 agents and toxins identified from the "HHS and USDA Select Agents and Toxins List."[2] Tier 1 agents are thought to be at particularly high risk for deliberate misuse.[3] Five additional agents are also included: pandemic influenza, endosulfan, chlorpyrifos, *Ralstonia solanacearum*, and citrus greening disease. Influenza is included due to its known potential impacts on human health as well as infrastructure. Endosulfan and chlorpyrifos are highly toxic chemical compounds that have a history of use as pesticides; food and/or water contamination are potential concerns. Two plant diseases were added as well to ensure coverage for this important NBIS domain.

The agents listed below include the human, animal, plant, food, and environment (HAPFE) categories that NBIC is charged with monitoring. Because of significant differences in the means of exposure, the types of models required can vary greatly between agents, and it is acknowledged that there may be gaps in the available model coverage. This list is not meant to be comprehensive but to provide a range of high-priority agents and toxins suitable for analysis using BioCat models.

**Table D.1.** Prioritized Agents of Interest for BioCat Analysis

| Agent | NBIS Domain Affected |
|---|---|
| ***Bacillus anthracis*** | Human, Animal, Environment |
| **Botulinum toxin** | Food |
| ***Burkholderia mallei*** | Human, Animal |
| ***Burkholderia pseudomallei*** | Human, Animal |
| **Chlorpyrifos (Dursban)** | Environment, Food |
| **Citrus Greening, Huanglongbing (HLB) of citrus, *Candidatus Liberibacter americanus*** | Plants |
| **Endosulfan** | Environment, Food |
| **Foot and Mouth Disease (FMD)** | Animal |
| ***Francisella tularensis*** | Human, Animal |
| **Influenza (pandemic)** | Human, Animal |
| ***Ralstonia solanacearum*** | Plants |
| **Rinderpest virus** | Animal |
| **SARS** | Human |
| **Variola (major and minor)** | Human |
| **Viral hemorrhagic fevers including Ebola and Marburg** | Human, Animal |
| ***Yersinia pestis*** | Human, Animal |

[1] List received from the client via email on April 10, 2013.
[2] http://www.selectagents.gov/select%20agents%20and%20toxins%20list.html
[3] http://www.asm.org/index.php/public-policy-2/97-policy/documents/8417-sa-10-9-12

# Appendix E

# Disease Forecast and Prediction Model Evaluation Metrics & Definitions

| Tier (1-3) | Term | Definition | Source | Staffing | Notes |
|---|---|---|---|---|---|
| 1 | **Event-type I** | First-pass identification of the disease, agent and vector of interest in the article. | | Tier 1 data collection will be conducted by a research associate. | |
| 1 | Disease Specific | The causative agent of the event being modeled is disease specific. | | | |
| 1 | Agent/Pathogen/Toxin/Pest | The agent(s)/pathogen(s)/toxin(s)/pest(s) of the event being modeled. | Client provided lists | | |
| 1 | Vector | An invertebrate that transmits a pathogen from reservoir to host. | | | |
| 1 | **Operational Aspects I** | First pass to identify characteristics of the model being evaluated. | | | |
| 1 | Event Prediction | The model predicts an event/outbreak is expected to occur in the future (left - before an event). | | | |
| 1 | Event Forecast | The model makes estimations about an event/outbreak occurring at some specified future date (the index case exists, what is the projected - estimated spread/trajectory/R0/infectivity/transmissibility). | | | |
| 1 | **Technological Maturity** | The level of maturity of a particular model in comparison to others. | | | |
| 1 | Verified or Validated | First-pass identification of whether or not the model has been verified and/or validated (Does the article mention any type of validation or verification?). | | | |
| 1 | **Model Identification I** | First-pass identification of the Model discussed in the article. | | | |

| Tier (1-3) | Term | Definition | Source | Staffing | Notes |
|---|---|---|---|---|---|
| 1 | Model Name | The name of the model (e.g., EpiCast, FLuTe, IT-CI, …). | | | |
| 2 | **Model Identification II** | Second pass and more detailed information extraction of the Model discussed in the article. | | Tier 2 data collection will be conducted by a post-doc, advanced undergrad/Master's level intern or S&E II/III. | |
| 2 | Owner | The "owner" of the model used in the article. This can be a person, university, corporation or organization. | | | |
| 2 | Website | The website where additional information about the model can be found. | | | |
| 2 | Corresponding Author | The article's corresponding author as identified in the full-text document. | | | |
| 2 | Corresponding Author Phone Number | The corresponding author's phone number as identified in the full-text document. | | | |
| 2 | Corresponding Author Email Address | The corresponding author's email address as identified in the full-text document. | | | |
| 2 | Model Creation Year | The year the model was created. | | | |
| 2 | Revision | Is this a modification of the original model (same owner or different). | | | |
| 2 | Revision Date | The date the model was revised/modified. | | | |
| 2 | This Model Rocks | This is a subjective opinion of the PNNL SME on whether this model is “cream of the crop” or “pit of the pot.” | | | |
| 2 | **Event-type II** | Second-pass identification of the affected population detailed in the article. | | | |
| 2 | Population (Species) Affected Identified | The specific affected population/species identified and modeled in the article. | | | |
| 2 | **Technological Maturity** | The level of maturity of a particular model in comparison to others. | Metrics for Evaluation draft report (2010) | | |

| Tier (1-3) | Term | Definition | Source | Staffing | Notes |
|---|---|---|---|---|---|
| 2 | Type of Validation and Verification | The method used to verify and/or validate the model's maturity. | | | |
| 2 | In Use in an Operational Environment | The model is or is not in use in an operational environment. | | | |
| 3 | **Operational Aspects III** | Third pass to identify characteristics of the model being evaluated. | | Tier 3 data collection will be conducted by an advanced post-doc/S&E III/IV | |
| 3 | Spatial | Models which forecast the geographic spread of a disease after it occurs based on the relationship between the outbreak and primary geospatial factors. | PLoS ONE Manuscript | | |
| 3 | Ecological Niche* | Computational models/algorithms to predict the distribution of species in geographic space on the basis of a mathematical representation of their known distribution in environmental space. | Wikipedia | | * Also called environmental niche modeling, species distribution modeling, predictive habitat distribution modeling, and climate envelope modeling. |
| 3 | Event-Based | Models which attempt to identify outbreaks either through sentinel groups or through the collection of real-time diagnostic, clinical, or syndromic data. | PLoS ONE Manuscript | | |
| 3 | Dynamical | Models which examine how a specific disease moves through a population. | PLoS ONE Manuscript | | |
| 3 | Statistical Models | Models which are a formalization of relationships between variables in the form of mathematical equations. | Wikipedia | | |

| Tier (1-3) | Term | Definition | Source | Staffing | Notes |
|---|---|---|---|---|---|
| 3 | Agent Based Model | Computational models for simulating the actions and interactions of autonomous agents (both individual or collective entities such as organizations or groups) with a view to assessing their effects on the system as a whole. | Wikipedia | | |
| 3 | Accessibility | The degree to which and mechanism by which the model is made available, e.g., plug-and-play, downloadable, etc. | Corley et al. (2012)[1] and modified as needed | | |
| 3 | Run Time, Complexity, Capabilities Required | Characteristics required for executing the model effectively. | | | |
| 3 | **Geographic and Population Coverage** | Geographic area and population size of the organism(s) being modeled. | | | |
| 3 | Input Geography | Geographic area attributes used as model input. | | | |
| 3 | Output Geography | Geographic area attributes generated as model output. | | | |
| 3 | Local | A geographic area bounded by city or county limits. | Based on LANL's work and modified as needed | | |
| 3 | Provincial/State | A geographic area within the political boundaries of one government, such as a province or state. | Based on LANL's work and modified as needed | | |
| 3 | Regional | A geographic area defined by similar features and location, such as the Columbia Basin or Latin America. | Based on LANL's work and modified as needed | | |
| 3 | National | A geographic area composed of a country. | Based on LANL's work and modified as needed | | |

[1] Courtney D. Corley, Mary J. Lancaster, et al. Assessing the Continuum of Event-Based Biosurveillance Through an Operational Lens. Biosecurity and Bioterrorism: Biodefense Strategy, Practice, and Science. March 2012. doi:10.1089/bsp.2011.0096. PNNL-SA-77400

| Tier (1-3) | Term | Definition | Source | Staffing | Notes |
|---|---|---|---|---|---|
| 3 | Global | A geographic area defined as the entire world/international in scope. | Based on LANL's work and modified as needed | | |
| 3 | Vector Population Size | The size of the vector population. | | | |
| 3 | Modeled Species Population Size | The population size of the species impacted. | | | |
| 3 | **Data Input** | Data input is a general characterization of the type of model used to produce results. | PLoS ONE and Corley et al. (2012) | | |
| 3 | Epidemiological Data from the Same Location | Models which take into account epidemiological characteristics of the disease from the same location. | PLoS ONE manuscript | | |
| 3 | Epidemiological Data from Difference Location | Models which take into account epidemiological characteristics of the disease from different same locations. | PLoS ONE manuscript | | |
| 3 | Governmental and Non-Governmental Organizations | Models which use data acquired from governmental or non-governmental organizations. | PLoS ONE manuscript | | |
| 3 | Literature | Models which use any form data excluding epidemiological, weather, or population data. | PLoS ONE manuscript and modified as needed | | |
| 3 | Satellite/Remote Sensing | Models which use data acquired via satellite or remote sensing technologies. | PLoS ONE manuscript | | |
| 3 | Simulated | Models which are simulated using software or statistical techniques. | PLoS ONE manuscript and modified as needed | | |
| 3 | Laboratory Diagnostic | Models developed using laboratory diagnostic data. | PLoS ONE manuscript | | |
| 3 | Expert Opinion | Models based on expert opinion - does not specify from whom or what type of data was used in the modeling. | PLoS ONE manuscript | | |
| 3 | **Output** | Output is the information/data/analysis produced after running a model. | Corley et al. (2012) and modified as needed | | |

| Tier (1-3) | Term | Definition | Source | Staffing | Notes |
|---|---|---|---|---|---|
| 3 | Output Content | Model output may be quantitative or qualitative and may include probabilities, forecasts, digests, counts, warnings, or lists of outlying observations. | Corley et al. (2012) and modified as needed | | |
| 3 | Sustainability | A measure of how long model output may be considered valid and confident. | Corley et al. (2012) and modified as needed | | |
| 3 | **Cost** | Cost represents the overarching financial investment (in USD) of purchasing the model, purchasing equipment to run the model, staffing expertise, and any other expense required to develop or sustain the model. | Corley et al. (2012) and modified as needed | | |
| 3 | Research, development, testing, and evaluation | The cost (in USD) to perform research, and to construct, prepare, develop, test, and evaluate the model. | Corley et al. (2012) and modified as needed | | |
| 3 | Operations | The cost to maintain and operate the model. This includes any projected storage, data acquisition, or staffing expense to maintain model performance. | Corley et al. (2012) and modified as needed | | |
| 3 | Government funded | A tribal, local, regional, national, or international governmental agency funded the development and/or operations of the model. | Corley et al. (2012) and modified as needed | | |

# Appendix F

# BioCat Evaluation & Workflow Data Fields

| Triage Level | Metric | Submetric | Required | Type of Field | Allowed Value | Notes |
|---|---|---|---|---|---|---|
| 1 | Event-type (I) | Disease Specific | Y | Yes or No (Radio / Drop Down) | | |
| | | Agent/Pathogen/Toxin/Pest | N | Check Boxes | | If Disease Specific is Y, then pop-up Agent selection |
| | | Vector | N | String Field (Manual) ';' separated | | |
| | Operational Aspect (I) | Event Prediction | Y | Yes or No (Radio / Drop Down) | | |
| | | Event Forecast | Y | Yes or No (Radio / Drop Down) | | |
| | | Verified or Validated | Y | Yes or No (Radio / Drop Down) | | |
| | Technological Maturity (I) | Model Name | N | String Field (Manual) | | |
| | Model Identification (I) | Second Look Required | N | Yes or No (Radio / Drop Down) | | If Y, trigger workflow AND hide this field from public/user view. |
| 2 | Model Identification (II) | Owner | N | String Field (Manual) | | Firstname Lastname |

| Triage Level | Metric | Submetric | Required | Type of Field | Allowed Value | Notes |
|---|---|---|---|---|---|---|
| | | Website | N | String Field (Manual) | | |
| | | Corresponding Author | Y | String Field (Manual) | | |
| | | Corresponding Author Phone Number | N | Phone Number | | Phone number with area code - US or international |
| | | Corresponding Author Email Address | N | Email Address | | Valid email address |
| | | Model Creation Year | N | Date | | Only Year is Required |
| | | Revision | N | Yes or No (Radio / Drop Down) | | |
| | | Revision Date | N | Date | | Only Year is Required |
| | | This Model Rocks | N | Yes or No (Radio / Drop Down) | | Hide this field from public/user view. |
| | Event-type (II) | Population (Species) Affected Identified | Y | Yes or No (Radio / Drop Down) | | If Population Y, prompt to fill in text box for Population Affected (see row below). |
| | | *Population (Species) Affected* | N | String Field (Manual) ';' separated | | If Population Y (above), prompt to fill in text box for names(s) of Population Affected. |
| | Technological Maturity (II) | Type of Validation and Verification | N | Drop Down | Statistical Verification | Need to be able to choose more than one. |
| | | | | | Sensitivity Analysis (verification) | |
| | | | | | Specificity and Sensitivity (verification) | |

| Triage Level | Metric | Submetric | Required | Type of Field | Allowed Value | Notes |
|---|---|---|---|---|---|---|
| | | | | | Verification using Training Data | |
| | | | | | Validation using Temporally Independent Data | |
| | | | | | Validation using Spatially and Temporally Independent Data | |
| | | | | | Second Look Required | Trigger workflow AND hide this field from public/user view. |
| | | In Use in an Operational Environment | N | Yes or No (Radio / Drop Down) | | |
| 3 | Operational aspects (III) | Type of Model | Y | Check Boxes | Spatial | Not mutually exclusive. Need to be able to choose more than one. |
| | | | | | Ecological Niche | |
| | | | | | Event-Based | |
| | | | | | Dynamical | |
| | | | | | Statistical Models | |
| | | | | | Agent Based Model | |
| | | | | | Other | If selected, provide string field (required). |
| | | SME Needed (Y/N) | N | Yes or No (Radio / Drop Down) | | |

| Triage Level | Metric | Submetric | Required | Type of Field | Allowed Value | Notes |
|---|---|---|---|---|---|---|
| | | Accessibility | N | String Field | | Pop-up suggestion: (plug-and-play, downloadable, etc.) |
| | | Run Time, Complexity, Capabilities Required | N | String Field | | |
| | Geographic and Population Coverage | Input Geography | N | Drop Down | Local | Need to be able to choose more than one. |
| | | | | | Provincial/State | |
| | | | | | Regional | |
| | | | | | National | |
| | | | | | Global | |
| | | Output Geography | N | Drop Down | Local | Need to be able to choose more than one. |
| | | | | | Provincial/State | |
| | | | | | Regional | |
| | | | | | National | |
| | | | | | Global | |
| | | Vector Population Size | N | Drop Down | 10s; 100s; 1000s; 10,000s; 100,000s, 1,000,000s | |
| | | Modeled Species Population Size | N | Drop Down | 10s; 100s; 1000s; 10,000s; 100,000s, 1,000,000s | |
| | Data Input (III) | Input Content | Y | Check Boxes | Epidemiological Data from the Same Location | |
| | | | | | Epidemiological Data from Difference Location | |

| Triage Level | Metric | Submetric | Required | Type of Field | Allowed Value | Notes |
|---|---|---|---|---|---|---|
| | | | | | Governmental and Non-Governmental Organizations | |
| | | | | | Literature | |
| | | | | | Satellite/Remote Sensing | |
| | | | | | Simulated | |
| | | | | | Laboratory Diagnostic | |
| | | | | | Expert Opinion | |
| | Output (III) | Output Content | Y | String Field (Manual) ';' separated | | Pop-up suggestion: (e.g., structured warning output, probabilities, etc.) |
| | | Sustainability | N | String Field (Manual) ';' separated | | Pop-up example: For how long are the forecasts/predictions confident? |
| | Cost (III) | Research, development, testing, and evaluation | N | Drop Down | $10s; $100s; $1000s; $10,000s; $100,000s, $1,000,000s | |
| | | Operations | N | Drop Down | $10s; $100s; $1000s; $10,000s; $100,000s, $1,000,000s | |
| | | Government funded | Y | Drop Down or Check boxes | Y, N, Not Indicated | |

Pacific Northwest
NATIONAL LABORATORY

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