Risk-based and Infectious Disease Epidemiological Modeling (RIDEM)

Mission Statement:
"Optimizing disease survey and management programs via risk-based modeling"

Our mission is to support integrated pest/disease management programs by providing risk-based and quantitative decision making tools for growers, policy makers, regulatory agencies, and applied researchers. In many respects, our group has made substantial contributions to the field of epidemiology. Focusing on integrated pest management and disease survey methodologies for urban and commercial agricultural landscapes, we strive to address some of the nation's most pressing issues in understanding how to prevent plant pathogens and pests from destroying commercially and economically significant agricultural and ecological resources. Our strong background in disease forecasting and modelling, plant biology and pathogenesis, ecology, microbiology, experimental design, and statistical analysis has allowed our research to be particularly innovative, with applications such as prognostic and proactive management strategies for different pathosystems vital to the economy, commerce, nutrition, and other cornerstones of healthy, robust societies.

Personnel:
Analysts & Modelers: Weiqi Luo, Drew Posny, Joy Rose
Technicians: Shuo Zhang, Leigh Sitler
USDA, ARS Research Leader: Tim Gottwald
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Background:
As pests/pathogens/biota spread, growers and regulatory agencies require timely investigative and prognostic tools in order to safeguard important crops. CIPM researchers in the Gottwald Epidemiology Lab at the USDA, ARS, Horticultural Research Laboratory, Fort Pierce, Florida are involved in a wide array of projects that fall under the umbrella of integrated pest and disease management such as investigating human-mediated introduction points and risk factors influencing pest/disease progression and establishment to target control. RIDEM's robust analytical/modeling tools can help agencies in refining existing pest detection programs and surveillance systems.
Key stakeholders that benefit from our research:

- USDA-APHIS, PPQ, CPHST
- California Department of Food and Agriculture
- Central California Tristeza Eradication Agency
- California Citrus Research Board
- Arizona Department of Agriculture
- New York Department of Agriculture and Marketing - Plant Industry - Plum Pox Eradication Program
- Florida Department of Agriculture & Consumer Services
- Texas Department of Agriculture and Marketing
- Department of Homeland Security and Florida Department of Health
- Growers, particularly Citrus or Stone Fruit
- State agencies responsible for conducting pest/disease surveys

- The American Seed Trade Association
- Applied researchers evaluating different management strategies

Goals and Objectives:

- Predict pest/pathogen/disease introduction and progression through advance mathematical framework, spatiotemporal modelling and simulations
- Incorporate historical, subjective and/or expert knowledge into formal statistical frameworks to predict risk of pathogen spread
- Develop risk-based survey tools to maximize early pest/disease detection
- Extract informative estimates of key epidemiological parameters
- Conduct field/greenhouse experiments to address knowledge gaps in disease epidemiology and inform model development
- Analyze effectiveness and economic-viability of pest/disease management programs
- Continue to provide updated informative measures (i.e. modelling and analysis outputs) to stakeholders, regulators and growers through user-friendly applications/interfaces and risk maps

Activities:

1. *Risk-based models analyzing invasive and exotic pests/diseases of plants(primary focus), animals and humans*

   Combining risk variables with geographic information system (GIS) data, we designed surveys and maps for stakeholders, helping facilitate the appropriation of fiscal and human resources for careful and cost-effective sampling.

   a. Citrus huanglongbing (HLB) and its vector, Asian citrus psyllid (ACP) risk-based models and surveys (statewide and high-intensive local) – CA, FL, TX, AZ
   b. Plum pox virus (PPV) risk-based models and surveys – NY, CA
   c. Statewide Multipest Survey – FL (multiple pests and specific for Citrus Black Spot (CBS))

2. *Citrus Health Management Area (CHMA) construction and ACP monitoring – CA, FL*

   Optimized the placement of CHMA boundaries according to similarity in disease intensity and pest populations, grouping regions with similar situations together for pragmatic evaluation and treatment.

3. *Spatially-explicit epidemiological models with early detection techniques (EDTs) and other control interventions*

   Demonstrated how to optimize plant disease intervention and management with simulations of plant pathogen spatial distribution. HLB/ACP models emphasizing:

   a. Mixed landscapes of residential/commercial citrus (Agent-based model)
   b. Grove dynamics (Webidemics extension model)

4. *Census travel model for disease/pest introduction, with extensions to local transmission risk models*

   Developed web application to model the effect of international travel on disease epidemics to predict the most likely locations for pest/disease introduction. Employing a geospatial method, the model integrates both U.S. census and international travel data with the epidemiological characteristics of various pathosystems to show which regions are most at-risk to disease introduction. The model has been deployed to predict introduction points of

plant diseases (e.g. CBS, HLB, PPV) as well as human diseases (e.g. Zika, Ebola, Chagas, Dengue Fever and Chikungunya). Web application: Census Travel risk model

Epidemiological models are coupled with the census travel model to further identify areas at-risk of local reproduction and dispersal, as well as how diseases interact with the landscape of agricultural and residential areas (e.g. Zika in Florida, HLB in California).

5. *Field/greenhouse experiments measuring spatial dispersal*
    a. Conducting wind tunnel experiments to quantify the effect of wind speed on dispersal of *Xanthomonas fragariae*, the causal agent of angular leaf spot of strawberry
    b. In collaboration with citrus growers in Collier County, Florida, field studies are planned to model the spatial pattern of CBS through three-dimensional characterization of symptoms within citrus tree canopies
6. *Measure effects of seed quality management practices on phytosanitary risk reduction*
   A Bayesian Belief Network model in which expert knowledge is fused with data is utilized to provide a robust tool for seed pathogen spread risk prediction.
7. *Advancing Markov Chain Monte Carlo (MCMC) modeling approach on individual tree settings into the quadratization case to improve computational efficiency for EpiStats.*

Metrics Outputs:

- Risk-based survey models in-use by various states
  Over 300 United States surveyors have utilized our group's survey methodology:
    - South and Central California, Southwest Arizona, Texas, and Florida (HLB/ACP)
    - California and Northwest New York (PPV)

  Specifically, these survey protocols have been primary employed by the USDA, APHIS-PPQ program and State Department of Agriculture.
- Identification of an optimal spatial scale for:
    - Pest Management Area (PMA) designations in CA
    - Citrus Health Management Area (CHMA) designations in Treasure Coast Area, FL for optimizing ACP control performance

Strengths:

- Multidisciplinary group of scientists with expertise in biology, phytopathology, epidemiology, mathematics, statistics, and GIS mapping tools
- Statistical consultancy for experimental design, data analysis and modelling
- Rich expertise in infectious disease modelling, emphasis on citrus pests/diseases

Opportunities:

1. Collaborate with Global Pest and Disease Database (GPDD) group to feed the information in GPDD into applications/models such as the Census Travel model to develop and improve early detection technologies

Future Plans:

1. Refine Census Travel Interactive Web Application for disease introduction prediction
2. Launch Agent-based model for HLB/ACP simulation across different landscapes online
3. Analyze human-mediated spread of feral swine

4. Develop tool to analyze effect of neighboring crops/landscape on disease risk
5. Analyze historical citrus reduction rate/pattern using high-resolution aerial images
6. Utility of social media data mining to analyze citrus pathogen/pest introductions, predict incursions and target control