Complex Disease Problems Across Scales: Perspectives on Advancing Disease Ecology with Trans-Disciplinary Research

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Symposium objectives

Solving complex disease problems requires trans-disciplinary research across scales to effectively integrate diverse data and expertise (Peters et al. 2018). In light of the 2019 meeting theme of Bridging Communities and Ecosystems: Inclusion as an Ecological Imperative, we assembled a symposium bringing together virologists, entomologists, ecologists, geographers, and modelers to discuss vector-borne disease ecology from multiple scales. A myriad of interactions among the virus, vector(s), host(s), and environment make up a complex disease system, and the symposium speakers provided perspectives on how their scales and interactions of interest fit into that system as well as where they see potential for trans-disciplinary collaborations. The speakers were from a variety of subdisciplines and scales of interest (from virology on the microscale to geography on the continental scale) and stages in career (from doctoral candidate to professor). The goal of the symposium was to bridge and augment the different subdisciplines along the virology–ecology spectrum by highlighting how collaborative teams can work (or have worked) together, how novel computational methods can be utilized, and how decision-making can be integrated with models.

Presentation summaries

The first presentation, given by Albert Auguste (Virginia Tech), set the stage with an overview of vector-borne disease diversity, transmission, and how the scales overlap to make the complex system. Examples of studies were given from vector–environment interactions (mosquito surveillance in different landscapes in Trinidad to gauge the impact of landscape change on arboviral emergence) to virus–host interactions. Further, Dr. Auguste presented research on the use of closely related insect-specific viruses to protect against arthropod-borne viruses that infect vertebrates (inoculating mice with a novel insect-specific flavivirus to protect against West Nile virus superinfection and vaccine development to retain that protection).

The next four presentations progressed through increasing spatial scales. Michael Strand (University of Georgia) continued the discussion by detailing how the gut microbiota within vectors affects arboviral transmission. The community members in the gastrointestinal tract of vectors are environmentally acquired and the larval site is the primary predictor of the gut community. This presentation elucidated how viruses, vectors, and the environment interact at a microscale.
Next, Sara Paull (University of Colorado Denver) provided a landscape perspective of these virus–vector–environment interactions by discussing how temperature and moisture affect vector abundance and arboviral transmission at different spatial scales and extents. At the site level, Dr. Paull discussed micro-climates and how well commonly available temperature data reflect what the mosquitoes experience. In the context of West Nile virus at a regional scale, Dr. Paull gave examples of how the most influential climate factors (e.g., number of weeks below freezing, within-season precipitation, and drought) differ among states and counties. Ultimately, micrometeorological models, along with better open access to fine-scale climate data, can improve predictions of mosquito populations and West Nile virus risk.

Katherine Young (New Mexico State University) transitioned the discussion to virus–vector–host interactions at the landscape to ecosystem scale. Young presented on the impact of land cover change (e.g., deforestation, agricultural expansion, or urbanization) on transmission spillover. In equatorial regions, where biodiversity is high but land cover data availability is relatively low, there is a need for augmenting human transmission monitoring with land cover classification and mosquito surveillance. Young described results of a field study in Sarawak for sylvatic dengue virus to compare the complexity of vector and host interactions across different land cover types.

Sadie Ryan (University of Florida) gave a broader perspective not just by utilizing larger spatial extent data, but by bringing in communication about disease risk into the discussion. Dr. Ryan described how to best inform people in management about disease risk: convey messages in maps, use quantiles of transmission to define risk labels, and build models at the scales relevant to decision-makers. At the regional scale, risk estimates should be converted to “people at risk” to communicate the concept of risk more easily. No matter the scale, communicating risk and uncertainty depends on what scale the decisions are being made and what uncertainty is important to decision-makers.

The final presentation discussed novel computational methods for integrating multiple interactions. Graziella DiRenzo (University of California Santa Barbara) described a model that includes how within-host dynamics affect between-host dynamics and vice versa, which needs to include data about the environment. The proposed integrated population model includes a host model of observation states and a pathogen model of infection probabilities. Although developed for pathogens, and not specifically for vector-borne diseases, the model can be tailed to a vector-borne system with parameter modifications.

Collectively, this session discussed complex disease systems with perspectives on multiple scales (from micro to continental) and interactions (among virus, vectors, hosts, and environment) with a forward-looking discussion on future needs and trans-disciplinary possibilities between virology and ecology. The discussion following the presentations focused on how modeling frameworks can explicitly account for uncertainty, the effect of cultural differences on how human surveys can be designed and collected, and research on mosquito movement patterns. Although the focus of the presentations was on disease ecology, the trans-disciplinary discussion is extendable to other studies of complex, multi-scale systems.

Literature Cited

Peters, D. P. C., et al. 2018. An integrated view of complex landscapes: a big data-model integration approach to transdisciplinary science. BioScience 68:653–669.