

The Rising Tide of Herpetological Disease Science and Management

The first Global Amphibian and Reptile Disease (GARD) conference was convened 4–10 August 2022 in Knoxville, Tennessee, USA to present and discuss the latest science information and management directions for multifaceted

DEANNA H. OLSON*

US Department of Agriculture, Forest Service, Pacific Northwest Research Station, Corvallis, Oregon 97331, USA

MATTHEW J. GRAY

Center for Wildlife Health, Department of Forest, Wildlife, and Fisheries, University of Tennessee, Knoxville, Tennessee 37996, USA

FRANK PASMANS

Wildlife Health Ghent, Faculty of Veterinary Medicine, Ghent University, Merelbeke, Belgium

LEON GRAYFER

Department of Biological Sciences, George Washington University, Washington, D.C. 20052, USA

MARK Q. WILBER

Center for Wildlife Health, Department of Forest, Wildlife, and Fisheries, University of Tennessee, Knoxville, Tennessee 37996, USA

E. DAVIS CARTER

Center for Wildlife Health, Department of Forest, Wildlife, and Fisheries, University of Tennessee, Knoxville, Tennessee 37996, USA

ANDREW A. CUNNINGHAM

Institute of Zoology, Zoological Society of London, UK

*Corresponding author; e-mail: deanna.olson@usda.gov

disease threats to herpetofauna. An impressive cadre of the world's leading experts in herpetological pathogens and parasites assembled to address the common aim: to reduce the occurrence, rate, and severity of emerging infectious diseases that are plaguing global amphibian and reptile populations to ensure their conservation for years to come.

The scope of the program and assembly was broad, especially regarding attendee affiliations and geographies, infectious agents considered, host taxa susceptible to infections, and disease subdisciplines represented. Professional development or scientific product goals were accomplished in seven workshops, including a diversity/equity/inclusion workshop that was open to all participants. Over 230 professionals from 25 countries attended the conference in person and online, including scientists, natural resource managers, policy makers, and stakeholders from the public (Fig. 1). Twenty-one conference sponsors contributed funds for 40 travel awards to students and early career professionals from nine countries, facilitating broad participation and inclusion of diverse perspectives. Half of the nearly 150 presentations were given by students, attesting to the growing involvement of early-career scientists in advancing knowledge of herpetological diseases. Over 15 pathogens and parasites were addressed, with considerable focus on three diseases listed by the World Organization for Animal Health (founded as the OIE: <https://www.woah.org/en/home>; 8 Aug 2022): *Batrachochytrium dendrobatidis* and *B. salamandrivorans* chytridiomycosis and Ranavirosis. Other



FIG. 1. Participants of the first Global Amphibian and Reptile Disease (GARD) conference in Knoxville, Tennessee, USA, 4–10 August 2022.

talks spanned topics including snake fungal diseases caused by *Ophidiomyces ophidiicola* (formerly *ophidiicola*) and *Paranannizziopsis* spp., invasive fish rhabdovirus infections of amphibians, herpesviruses, Perkinsea infections, the invasive snake lung pentastome parasite *Raillietiella orientalis*, and amphibian skin mites, leeches, and gastrointestinal parasites. Topics of presentations spanned disease ecology and evolution, immunological and microbiome defenses, and surveillance, monitoring, and One Health management strategies. The conference program including abstracts of presentations is available online (<https://tiny.utk.edu/GARD22>; 8 Aug 2022).

The outcomes of the conference were diverse. Keynote speakers and focal talks captured reviews of scientific advances, with considerable focus on the tremendous strides made in the identification and taxonomy of herpetofaunal pathogens, interacting factors with infection dynamics, and host responses. Louise Rollins-Smith (Vanderbilt University, USA) reported that despite complex host immune defenses including a protective skin microbiome, antimicrobial peptides in the skin, and lymphocyte-mediated cellular and antibody responses, amphibian chytridiomycosis is still frequently a lethal disease. Several other presentations also highlighted the unique nature of amphibian antimicrobial, antifungal, and antiviral immune responses, underlining the importance of garnering greater understanding of amphibian (and reptile) immunity. Indeed, throughout the meeting, several parallels emerged between immune strategies and disease in amphibians and reptiles. While we are only beginning to scratch the surface of these animals' immune efficacies and shortcomings, GARD has successfully granted a broader perspective into poikilothermic host-pathogen interactions. In this respect, a common theme in many presentations was the importance of temperature and thermal dynamics of disease processes, contributing to a better understanding of host-pathogen disease ecology and host physiological responses. Several gaps in knowledge were identified. For example: 1) Jesse Brunner (Washington State

University, USA) pointed out that “we (largely) do not know how much ranaviruses threaten host populations” and we need “more consistent widespread longitudinal surveillance”; 2) Anthony Waddle (University of Melbourne, Australia) captured a sentiment alluded to in several talks that, simply, we “need ways to conserve frogs in nature”; and 3) the role of human activities on the emergence and spread of pathogens and parasites was raised in many different talks, with no real solution offered due to sociopolitical hurdles, despite One Health goals presented by Andrew Cunningham (Zoological Society of London, UK) to “optimize health of people, animals, and ecosystems” being elevated internationally. The applied sciences of disease mitigations are a much-needed research focus now and warrant elevated inclusion in future conference sessions. Nevertheless, in all there was a palpable energetic and scholarly tone to the first GARD conference, in presentations and the social networking evident at breaks and social hours. We predict this first GARD conference will springboard several new directions for herpetofaunal disease research collaborations in years to come and we look forward to further GARD conferences being held in the future.

Acknowledgments.—We thank the following sponsors for their generous funding support of the 2022 GARD conference: National Science Foundation, University of Tennessee Institute of Agriculture, Deutsche Gesellschaft für Herpetologie und Terrarienkunde, Environment and Climate Change Canada, Morris Animal Foundation, New Mexico Game and Fish Department, North Carolina Wildlife Resources Commission, Tennessee Tech University, Tennessee Wildlife Resources Agency, Wildlife Disease Association, Amphibian Survival Alliance, Missouri Department of Conservation, Nashville Zoo, Omaha's Henry Doorly Zoo and Aquarium, U.S. Geological Survey, Association of Zoos and Aquariums, Fort Worth Zoo, Tennessee Chapter of The Wildlife Society, Tennessee Herpetological Society, The Nature Conservancy, and Zoo Knoxville.