Transformational Principles for NEON Sampling of Mammalian Parasites and Pathogens: A Response to Springer and Colleagues


Seen as an opportunity to establish a nationwide web of environmental monitoring sites (Kao et al. 2012), the National Environmental Observatory Network (NEON) is now releasing a series of protocols presented with apparently broad community support. Springer and colleagues (2016) outlined sampling designs aimed at understanding how changing environmental conditions will affect mammals and associated parasites. They present a compelling case: [Parasites] can be important drivers of ecological and evolutionary changes in natural, agricultural, and urban ecosystems. These changes could also have unanticipated effects on ecological communities at large, particularly when individuals of constituent species play influential roles in community-level interactions or ecosystem function.

. . . As the size and scope of surveillance efforts expand, appropriate sampling design and methodological standardization will greatly facilitate comparisons across data sets and scales. Although logistically challenging, such large-scale, standardized sampling efforts are critical to characterize regional, continental, and multi-decadal patterns of disease dynamics. Insights gleaned from such projects hold promise for informing efforts to promote human health and wildlife conservation while furthering our fundamental understanding of the ecology and evolution of host–parasite interactions in natural systems.

Although the argument for studying parasites is clear, the proposed protocols are too limited to advance the understanding of ecological (much less evolutionary) responses to species invasions, changes in climate, and land use (Kao et al. 2012) or even the long-term dynamics of rodent–parasite systems. We offer a critique and an expanded vision for NEON's mammal–parasite protocols beyond select tick-, mosquito-, and rodent-borne pathogens. We encourage expanded sampling of (a) the parasite assemblage and (b) the host assemblage, along with (c) a two-pronged sampling design based on both rigorous sample archival and “mark-release” approaches. To fail to do either (a) or (b) excludes the possibility of both community- and ecosystem-level perspectives, and failure to do (c) effectively excludes sample-based studies and future work using yet-to-be-developed technologies. Reflecting on the long and highly productive history of specimen-based research (e.g., Suarez and Tsutsui 2004), we encourage NEON to take a more holistic, synergistic, and sample-intensive approach as a basis for long-term environmental observatories. Investment in NEON comes at a time when discoveries in ecology have exploded as a result of informatic and molecular tools that harness links among data types (e.g., geospatial, anatomical, genomic, physiological, and biological interaction traits). Tackling exceedingly complex environmental questions calls for holistic approaches that are reproducible and based on object-based links. Importantly, simple modifications would require minimal changes and costs to the expensive mark-release NEON protocols proposed and result in a much more productive platform.

To assess change, a broadly comparable infrastructure that includes deep sample archives across NEON sites is required. Sample-based research is huge and growing, with links among elements of biodiversity forming the crux for progress in both established and emerging fields. Microbiome, isotopic, and molecular ecology, as well as specimen-based metagenomics, transcriptomics, and proteomics, all depend on samples that can be tied back to the original organism. In addition, individual-level links represent the key for investigating networks of biotic interactions in community ecology and molecular biology (e.g., pathogen X found in tissue Y of mammal individual Z, corresponding to mammalian DNA sequence A and expression profile B; Morales-Castilla
et al. 2015). Such sampling also reinforces the fundamentals of scientific research: verification, replication, extension, and integration across studies. To maximize impact, the infrastructure deployed in NEON should provide not only observational data but also comprehensive sampling of parasitic organisms and their mammalian hosts, along with a commitment to the permanent archiving of samples in appropriately accredited repositories. As Springer and colleagues (2016) recognize, parasitism is a major driver of ecological systems (estimated at greater than 50 percent of all biodiversity) and represents an important source of zoonotic infections (e.g., Daszak et al. 2000, Hoberg et al. 2015), but the proposed NEON protocols lack a balanced effort to study parasites. For example, helminths are a highly diverse assemblage (three phyla parasitize rodents) that is best assessed by direct field sampling and archival development. We recommend separate removal tralines followed by comprehensive necropsies during specimen preparation. Because parasitic worms often have complex life cycles that are affected by numerous biotic and abiotic factors, they are exquisite indicators of environmental change. NEON’s limited effort to build archives represents a missed opportunity to maximize the impact of federal funds over time. The irony of focusing entirely on mark-release efforts is that such restricted (and expensive) activities severely limit our view of known parasites and seldom result in discoveries of new pathogens. In a textbook example of an emerging infectious disease in modern times, museum archives led to the original discovery of the devastating Sin Nombre hantavirus (Yates et al. 2002, DiEuliis et al. 2016) and subsequent transformative revelations that hantaviruses have a deep history with mammals and are widespread not only in rodents but also in shrews, moles, and bats on multiple continents (Yanagihara et al. 2014).

More generally, limited sampling of diversity is unlikely to stimulate powerful integration among projects or to foster synthetic perspectives in ecology, evolution, or biogeography. NEON protocols (e.g., Springer et al. 2016) should engage the broader ecological community and take advantage of existing and proven biodiversity and ecological infrastructure (permanent museum archives with taxonomic expertise, Web-accessible and interconnected databases, object tracking of samples, digital links to publications and other research products, etc.). Rather than leverage existing assets and expertise, the proposed protocols attempt to reinvent a wheel that has already been fine tuned by decades of effort expended by countless experts in field sampling, specimen curation and loaning, and big-data management and connectivity.

Because NEON has suffered setbacks (Mervis 2015) and is still in the relatively early stages of implementation, now is the time to improve and enhance protocols for the next 30 years. Careful consideration should be given to the consequences of failing to develop temporally deep and spatially extensive archives of organisms. Available technology and the questions of interest will evolve in the coming decades—vouchering specimens from a broader taxonomic range will maximize opportunities for future insights and productivity. Protocols should be reconfigured to ensure the expanded development of extensive, holistic archives of diverse taxa with targeted sampling minimally during four periods annually at NEON sites. Each holistic specimen becomes an “observatory” of environmental conditions, so extensive archives for host species (multiple tissues) and associated parasites (helminths, arthropods, gut microbiomes, viruses, protozoa, and bacteria) will further facilitate access to basic ecological information and deep understanding about fine-scale interactions in complex host–parasite assemblages. Investment in this extended infrastructure is relatively inexpensive, and the value of such an approach is proven (Malmstrom et al. 2007, Moritz et al. 2008). In particular, integrated understanding of the linkages and dynamics of hosts and parasites is essential to providing a pathway to identify emerging impacts of environmental perturbation, direct threats to ecosystem integrity, and animal and human health (Brooks et al. 2014). A holistic foundation for NEON represents a singular opportunity to develop crucial, long-term infrastructure for North America and a powerful synergistic model for ecosystem assessment globally. Only through such approaches can the observatory truly transform our understanding of environmental change.

References cited


Viewpoint

Joseph A. Cook (tucojoe@gmail.com), Stephen E. Greiman, and Jonathan L. Dunnum are affiliated with the Museum of Southwestern Biology and Biology Department at the University of New Mexico, in Albuquerque. Salvatore J. Agosta is affiliated with the Center for Environmental Studies and Department of Biology at Virginia Commonwealth University, in Richmond. Robert P. Anderson is affiliated with the Department of Biology at the City College of the City University of New York, in New York. Brian S. Arbogast is affiliated with the Department of Biology and Marine Biology at the University of North Carolina at Wilmington. Robert J. Baker and Robert D. Bradley are affiliated with Texas Tech University Biology Department and the Museum of Texas Tech University, in Lubbock. Walter Boeger is affiliated with the Universidade Federal do Paraná, in Curitiba, Brazil. Daniel R. Brooks is affiliated with the H. W. Manter Laboratory of Parasitology at the University of Nebraska, in Lincoln. Rebecca Cole is affiliated with the US Geological Survey, National Wildlife Health Center, in Madison, Wisconsin. John R. Dembski is affiliated with the Denver Museum of Nature and Science, in Colorado. Andrew P. Dobson is affiliated with the Department of Ecology and Evolutionary Biology at Princeton University, in New Jersey. Ralph P. Eckerlin is affiliated with the Mathematics, Science, and Engineering Division at Northern Virginia Community College, in Annandale. Jacob Esselstyn is affiliated with the Museum of Natural Science and Department of Biological Sciences at Louisiana State University, in Baton Rouge. Kurt E. Galbreath is affiliated with the Department of Biology at Northern Michigan University, in Marquette. John Hawdon is affiliated with the George Washington University School of Medicine and Health Sciences, in Washington, DC. Hopi E. Hoekstra is affiliated with the Department of Organismic and Evolutionary Biology and the Museum of Comparative Zoology at Harvard University, in Cambridge, Massachusetts. Susan J. Katz is affiliated with the University of Calgary’s Faculty of Veterinary Medicine, in Alberta, Canada. Jessica Light is affiliated with the Department of Wildlife and Fisheries Sciences and Biodiversity Research and Teaching Collections at Texas A&M University, in College Station. Link E. Olson is affiliated with the University of Alaska Museum at the University of Alaska, Fairbanks. Bruce D. Patterson is affiliated with the Field Museum of Natural History, in Chicago, Illinois. James L. Patton is affiliated with the Smithsonian Institution, National Museum of Natural History, in Washington, DC. Hoberg is also affiliated with the US Department of Agriculture, Agricultural Research Service in Beltsville, Maryland. Eric Rickart is affiliated with the Natural History Museum of Utah, in Salt Lake City. Duke S. Rogers is affiliated with the Monte L. Bean Life Science Museum and the Department of Biology at Brigham Young University, in Provo, Utah. Mark E. Siddall is affiliated with the American Museum of Natural History, in New York, New York. Vasyl V. Tkach is affiliated with the Department of Biology at the University of North Dakota, in Grand Forks.

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