

Proposal Title: *Land Management For Healthy People*: controlling human disease through ecosystem management.

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Description of the discovery opportunity: ESF's mission is to advance knowledge and skills and to promote the leadership necessary for the stewardship of both the natural and designed environments. ESF is at the nexus of people and their environment and therefore is positioned to excel in understanding how human health is increasingly impacted by our natural and built environment. Most notably are the emergence and re-emergence of numerous zoonotic diseases (diseases transmitted from animals to humans) such as Ebola and Zika virus, Avian Influenza, and Lyme disease. It is estimated that 60% of all emerging disease have a non-human animal source and ~72% of these are caused by agents with a wildlife origin. Globally, more than one-half of the world population is at risk for contracting a vector-borne and zoonotic disease (VBZD) with more than one billion infections and one million deaths annually. In the U.S., the number of vector-borne diseases reported to the Centers for Disease Control (CDC) has more than doubled from 2004-2016. VBZD emergences have greatly increased due to anthropogenic activities. For example, deforestation and expansion of agriculture have driven increased contact between humans and monkeys and subsequent Ebola outbreaks in West Africa. Dam construction and water regulation are expanding habitat of the intermediate snail host for human schistosomiasis in central China. And, reforestation and deer population explosion in the Northeastern US are currently fueling the expansion of various tick-borne diseases (including Lyme). There is a global push to understand emerging infectious disease through the lens of "One Health," a concept that intrinsically links the health of humans, animals and the environment. This concept has been adopted by both human and animal health fields but lacks significant engagement from the environmental sciences (especially the fields of conservation and ecology). ESF's legacy as an institute focused on research and teaching in the context of the Environment as well as our proximity to SUNY Upstate Medical University uniquely position our institution to become a flagship program within the SUNY system and a global leader in the field of Environmental Health.

The overarching goal of this Discovery Challenge proposal is to capitalize on multidisciplinary strengths at ESF and become a model program for advancing the theory and practice of using ecosystem level management strategies to modify human disease risk. This goal will be achieved by:

1. Assembling a leading team of interdisciplinary researchers capitalizing on traditional institutional strengths in the fields of natural resources management, landscape architecture, conservation biology and ecology.
2. Apply team knowledge and skills to modify disease risk in the environment using Lyme disease as a model system.
3. Establish a teaching and training program that will serve as the foundation for integrating multiple disciplines and preparing graduates with the requisite knowledge and practical skills to integrate dimensions of health into the environmental sciences.

Lyme disease is a model system to test the effects that ecosystem level management techniques will have on an emerging disease of great concern and interest to the public. The emergence and spread of Lyme disease are secondary to multiple environmental changes (e.g., fragmented reforestation and increased deer populations) and forces (climate change). The causative agent for Lyme disease, *Borrelia*

burgdorferi, has a complex enzootic cycle which involves the tick vector, various vertebrate reservoirs (small mammals and birds) and larger mammals which are often refractory to *B. burgdorferi* infection but contribute to Lyme disease ecology by providing an ample source of blood to a large numbers of ticks. The capacity for *B. burgdorferi* to cause severe disease varies by genotype, and genotypes are associated with particular vertebrate species. These associations present an opportunity to modify disease risk to humans in nature through the manipulation of habitats and thereby the shaping of vertebrate community structure and density. *B. burgdorferi* distribution is highly connected in its landscape, especially in areas of recent expansion. Bacterial genotypes are more likely to spread through short distance terrestrial mammal movement than through long distance (bird, deer) dispersal. Therefore, managing ecosystems to create small mammal predator habitat in key areas and introducing landscape features such as pine or conifer stands that do not support tick development may serve as barriers that stop or slow disease spread.

Because ticks spend 99% of their life off their host, environmental factors such as abundance of trees, canopy height, sapling tree density, depth of leaf litter, soil type, and abundance of herbaceous vegetation play a significant role in tick survival as well as their presence and density in the landscape. Stand and other land management strategies hold the potential to affect many of these factors directly influencing tick survival and human disease risk.

Inherent to any human disease system is how we perceive and understand disease risk. Because human diseases are intrinsically influenced by environment, risk mitigation often drives people to take drastic measures to control disease. Examples include the wide spread culling of pig and waterfowl in recent influenza outbreaks, and forest avoidance behaviors due to tick-borne diseases in the Northeastern US. As part of this initiative we will employ social science methodology to understand the public's perception of disease risk in the environment (especially in the context of Lyme) and how this can be coupled with management strategies to reduce unwarranted fear.

(2) Program impact and student advancement. A cornerstone of this initiative will be to develop a cross-disciplinary certificate program entitled "Land Management for Healthy People." This certificate will equip participants with practical knowledge on how silviculture and other land management practices influence human health so that predicted effects on human health will be used as a metric in decision making. The program will be non-residential, thus will offer appropriate existing and new on-line courses through ESF's Open Academy. ESF undergraduates will be able to earn a minor in this area by taking courses offered in the collection and analysis of ecological and disease data. Within the context of this initiative ESF students will gain valuable knowledge, skills and practical experience tackling real-world problems at the intersection of the environment and human health. These skills will set apart ESF students especially in the expanding fields of Environmental and Public Health.

(3) A list of agencies, partners, and funding entities: We anticipate significant funding opportunities based on outcomes generated by this initiative including research and training funding through the NSF-NIH EEID (Ecology and Evolution of Infectious Diseases) program (Eight-R01 awards available for FY19), NSF Long Term Research in Environmental Biology (LTREB) (\$6,00,000 in FY2018) program, the New York State Senate Tick Task Force (\$1,000,000 earmarked in FY18), the USDA (Forestry Legacy Program, Landscape scale restoration and conservation), the Sustainable Forestry Initiative, NYSERDA, NYSDEC, as well as non-profit organization and philanthropic donors.

(4) Partnership creation and expansion: Investment in this initiative will immediately expand SUNY-ESF's partnership with the Fullers Overlook property and its owners where tick-borne disease

research currently is being conducted. We also see significant interest and partnership with programs supported by the NYDEC including NY mammal mapping efforts and NYSDEC's Young Forest Initiative. Because of the nature of the proof of concept study proposed as part of this initiative we expect significant engagement by new and existing partners interested in the control of Lyme and other tick-borne diseases.

(5) Use of ESF assets beyond the Syracuse main campus: This initiative will leverage college-owned properties as well as lands currently utilized by various investigators at ESF, in particular the New York City Watershed Model Forest System in the Catskill region. Current courses offered by FNRM and EFB will be used as a setting to engage ESF students in generating data at planned study sites, especially where current field teaching is ongoing (Heiberg Forest, the Fullers Overlook and NYC Watershed Model Forests). Faculty involved in this initiative will be encouraged to offer courses that engage students in multiple aspects of this project especially as it relates to field work and the gathering and analyzing of ecological and disease data.

(6) Initiative impacts: Bring immediate attention to ESF as an institution leading the charge to improve the health of both humans and their environment. ESF is recognized as a leader in environmental issues however support for this initiative will bring significant attention to ESF as Lyme and other tick borne diseases are of great interest to the general public, media outlets and governmental officials. Funding for this initiative will provide a platform and example for ESF to demonstrate its commitment in improving human health through its strengths as a leader in the environmental sciences.

Develop and incorporate tools for quantifying health metrics in traditional environmental sciences as well as demonstrate their use and benefits. Forest managers use various practices to obtain desired outcomes. Forests are comprised of stands from 10s to 100s of acres. Silvicultural prescriptions at the stand level can serve as models for various management goals. To our knowledge human disease (e.g., Lyme) presence is not a metric currently considered in silvicultural applications despite its ease of measurement and its relevance to human health. We envision ESF spearheading the use of this metric and the characterization of forest for various emerging diseases around the globe. Conservationists promote biodiversity as a tool to perturb and recover from disturbances such as non-native invasions and disease. In disease systems, biodiversity may also reduce human disease risk from zoonotic pathogen. Therefore, measures of human disease risk may provide an additional metric for scientists to promote the importance and direct benefits of ecosystem management to various stakeholders including the general public. Promoting biodiversity in terms of preventing disease in one's backyard could help drive significant support for management sciences.

(7) Investments required: Because SUNY continues to make significant investments in Environmental Health as evidenced by SUNY 2020 commitment to the formation of the SUNY Center for Environmental Health and Medicine as well as the recent Empire Innovations Grant supporting hires of established investigators at both ESF and Upstate in support of the center, the foundation on which we propose the initiative is already in place. Three year funding under this proposal will support: A postdoctoral fellow, support for graduate and undergraduate student researchers, supplies for research and land management efforts, and salary support for faculty (especially to support the graduate certificate program).

Transformative Potential. ESF has capitalized on recent growth in the field of Public Health with the recent formation of its Environmental Health major, however, the institution has a timely opportunity to expand numerous ESF programs by developing research projects that capitalize upon our environmentally-focused departments and human health. The environment plays a critical role in the majority of the world's most pressing health concerns. The WHO estimates 23% (12.6 million) of all deaths globally are attributable to the environment. Current research in environmental health is largely focused on the role that environmental exposures, from factors such as water and air pollution, have on human health. Many of these hazards are human driven and significant policy and regulations provide guidance on these issues. Despite evidence that ~60% of all emerging human infectious diseases are zoonotic (animal origin), disease research is dominated by the medical and veterinary sciences where significant effort is placed in the development of vaccines, novel therapeutics, and preventative countermeasures. Because these diseases are inherently linked to the environment, ESF stands to make a significant impact on understanding drivers of global emerging zoonotic diseases. As a model of institutional strength, this initiative will unite a multidisciplinary team of researchers and apply their expertise and technical skills to address knowledge gaps in the expansion and risk of Lyme disease, an emerging disease threat in the US, employing ecosystem level management strategies.

Feasibility & Sustainability. A significant strength of this proposal is the ability to expand ongoing institutional research and programs under the umbrella of "Ecosystem Management and Human Disease". This initiative builds upon core institutional strengths (Forest Management, Ecology, Conservation Biology, and Landscape Architecture) as well as expands current collaborations with Upstate Medical researchers strengthening this proposal's path to sustainability. Although initial funding and success measures are focused on Lyme and other tick-borne diseases (TBDs), Human interactions throughout the complex environment provides ample opportunity to expand beyond TBDs into health issues like mosquito-borne malaria, viral hemorrhagic disease like Ebola, and more recent fields of inquiry like health impacts of outdoor and greenspace experiences. In addition to providing seed funds to three major objectives (below), this initiative is positioned to integrate into and utilize recent investments by SUNY in Environmental medicine, vector-borne diseases, and partner with current efforts to strengthen data science on "The Hill".

Research: Supporting ongoing projects via seed funds across campus and provide opportunities for students to assess the potential effect ecosystem modification has on disease risk using both field and laboratory skills. Examples include the effects invasive vegetation (Leopold), vertebrate diversity (Farrell, Frair, Gibbs), and silviculture (Germain) have on Human TBD risk (Leydet). Human disease and risk have a prominent social dimension. Under this initiative we will also explore environmental (Hoffman) and risk (Stewart) perception impacts on risk. Expanding upon ongoing research efforts with the support from this initiative will allow for the rapid generation of preliminary data for the submission of national level competitive funding in the various focus areas.

Education: Development of a graduate certificate program entitled "Land Management for Healthy People" will allow ESF to recruit and train students interested in bridging landscape and human health. To our knowledge this program would be the first-of-its-kind in the US in development with ESF Open Academy we assure the ability to recruit a significant number of students. The on-campus engagement of researchers from multiple disciplines will allow for the expansion of themes from this initiative into various undergraduate programs at ESF as well as offer significant research opportunities to the ESF student population.

Outreach: This initiative will receive significant interest from the public, media and politicians; especially given how salient the subject of Lyme and other tick-borne diseases are in the US. This attention provides a significant platform for ESF to promote the critical nature of environmental research as well as supply the development office with significant materials and resources to help recruit alternative funding sources (i.e. philanthropic dollars).