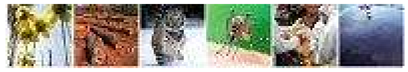


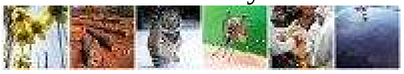
EPA Regional Science Workshop

Biodiversity/Landscape Change and Lyme Disease: Science and Application

EPA-New England Regional Laboratory, Chelmsford, MA

September 22-23, 2009

WORKSHOP PROCEEDINGS



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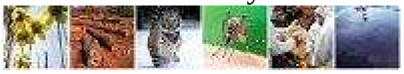

EXECUTIVE SUMMARY

In the northeast United States, Lyme disease (LD) infection rates and geographic range continue to markedly increase, and new research shows links between land use, biological diversity, and LD transmission. Improved understanding of these links can have an important impact on our understanding of the services provided by natural ecosystems and inform new management strategies to protect the environment and public health. EPA is building partnerships through establishment of a Community of Practice (CoP) around the issue of biodiversity/landscape change and vector-borne (Lyme) disease. It is hoped this CoP will foster closer collaboration between diverse communities, including public health practitioners, land use planners, ecologists, and the public. EPA is interested in addressing public concerns on LD by identifying best management practices related to land use and guidance on individual risk reduction. EPA is working with stakeholders through Green Infrastructural approaches to reduce adverse impacts to the landscape from development, to maintain upland and aquatic habitat integrity, for example, through minimizing forest habitat fragmentation, and to lessen adverse effects on human health. EPA also has a significant role in developing and implementing environmentally-based approaches under Integrated Pest Management (IPM) to improve control of vector-borne diseases on a landscape scale while reducing exposures to toxic chemicals.

In partnership with the EPA Office of the Science Advisor, the EPA New England (EPA-NE) Regional Science Council convened the first interdisciplinary forum of researchers, practitioners, and decision-makers in ecology, public health, and land use planning, to present emerging science linking land use, biodiversity, and LD transmission and to consider applications of this new science in LD management. The forum was an outreach effort to researchers, decision-makers, practitioners, and managers to increase awareness of the emerging science; to learn stakeholders' needs and priorities; to consider management options; and, to begin developing a multidisciplinary Community of Practice (CoP) to facilitate collaboration to address and manage LD as an integrated and cross-sectoral issue.

The workshop consisted of presentations on various topics related to changes in biodiversity, land use, and impacts on human disease. Experts shared knowledge on LD epidemiology, tick management, environmental and landscape factors affecting LD transmission (field experiments and modeling applications), and green infrastructure and land use planning approaches that could serve as vehicles for implementing environmentally-based tools for LD prevention and control. The presentations informed four diverse breakout/discussion groups of attendees which were charged with identifying:

- information needs for integrated decision-making;
- how to integrate information sharing and decision-making;
- research most useful for decision-making and management; and,
- environmental strategies and models to manage public health risks.

The multidisciplinary breakout discussions were aimed at building a CoP on biodiversity/landscape change and LD: they fostered sharing of knowledge and diverse perspectives among workshop attendees (*community*) and identified next steps towards applying emerging science to improve decision-making and management of risks to public health and the environment (*practice*). Through a variety of perspectives and disciplines, the workshop identified needs for:

- further multidisciplinary research at appropriate public health and ecological scales;
- *transdisciplinary* research which involves decision-makers in the research process from the problem formulation stage;
- field research on the diversity (composition, abundance) of animal hosts along a fragmentation gradient;
- studies to increase understanding of how landcover configuration and connectedness (landscape pattern) affect LD risk;
- a better understanding of how animals (including humans) and disease vectors involved in the LD life cycle move through the environment as a result of land use change;
- the use of veterinary indicators of public health risk;
- the development of an integrated toolbox of strategies and approaches, as part of Integrated Pest Management (IPM), made available for local managers of LD;
- post-implementation monitoring with scientific evaluation to assess the effectiveness of disease mitigation research applications; and,
- clear and consistent communication on risk prevention and management.

Policy interventions related to land use planning, low impact development, Green Infrastructure, Smart Growth, conservation, ecosystem management, and human disease risk reduction can all be part of integrated pest (vector) management (IPM) strategies, and reducing LD risk could involve a combination of these, depending on the local context and ecology. Participants identified the need for future discussions beyond this pilot workshop, inviting additional experts from geography, the social/behavioral sciences, and landscape architecture and planning, to participate in the CoP.

Biodiversity, Landscape, and Lyme Disease Linkages

Lyme disease is the vector-borne disease with the highest incidence in the U.S., with nearly 29,000 confirmed cases reported in 2008 by CDC, and probable cases likely exceeding 35,000. From 1992-2006, nearly 250,000 confirmed cases were reported in the 50 US states and Territories, with most cases clustered in the Northeast and upper Mid-West. The human risk varies geographically and is dependent upon the local distribution and abundance of vector-competent tick species and the available vertebrate host community, such as white-footed mice and white-tailed deer (*Odocoileus virginianus*), upon which the ticks across their various life stages depend. Immature ticks acquire the LD bacteria by feeding on infected small mammals such as white-footed mice (*Peromyscus leucopus*) and eastern chipmunks (*Tamias striatus*). Not all mammals are equally effective or efficient at transmitting the disease to ticks. White-footed mice appear to be the most effective (or "competent") when it comes to transmitting LD-causing bacteria to ticks. In the Northeast US, white-footed mice are the dominant animal hosts of the LD bacterium (*Borrelia burdorferi*). Greater numbers of competent hosts and greater numbers of tick vectors that become infected from feeding on them are associated with higher human LD risk. The "dilution" effect predicts lower rates of LD infection in highly diverse vertebrate animal communities, where the presence of less "competent" hosts can dilute rates of transmission between white-footed mice and feeding ticks. There is evidence to support positive impacts on public health related to highly diverse animal communities. At the same time, parasites can be important drivers of biodiversity and components of ecosystem health. Although additional animal hosts can reduce the transmission rates of particular diseases, they may harbor other pathogens. The relationships between biodiversity/landscape change and human LD risk are complex, and research is continuing (and more is needed) to better characterize their interrelationships.

Some LD research has been focused on the nymphal tick life stage because it is the first stage capable of transmitting disease to humans. Its peak biting activity coincides with summertime when people are more likely to be outside and recreating in at-risk areas; and, the nymphal tick is small enough to be overlooked on human skin after feeding. There are ongoing field studies in New York State to characterize the mechanisms by which ticks become infected and how the diversity of small vertebrate mammals and birds impacts this process. It appears that the abundance of white-footed mice is predictive of both the density of infected tick nymphs and the LD risk in the human population.

A variety of ecological regulatory mechanisms – at the level of the pathogen, tick vector, animal host - acting independently, can help explain how LD transmission[1] is affected by changes in vertebrate animal biodiversity.[2] Improved characterization of these mechanisms can help determine the generalizability of the biodiversity-LD relationship to other geographic locations, and, perhaps, to other disease systems (e.g. West Nile virus). It is unclear what ecological spatial scale is most appropriate to define the animal host community (as it relates to tick infection rates) in order to interpret and potentially manage public health risk. Many types and sizes of spatial units have been studied, from the backyard to landscapes measuring hundreds of square kilometers, with significant relationships found across scales among indicators of disease risk.

Previous studies suggest that there is a connection between the abundance of animal hosts and tick vectors and the landscape they inhabit. Allan et al. (2003) observed that the makeup of animal host communities is largely determined by how intact the forest habitat is (lack of fragmentation). Forest fragmentation and destruction in the U.S. have been shown to reduce mammalian species diversity and to increase populations of the white-footed mouse. Researchers at EPA are investigating whether the degree of fragmentation can serve as a surrogate for the density of infected ticks and therefore, public health risk. A model has been developed to predict LD risk by the spatial configuration of forest and herbaceous cover. In Maryland, where exposure to Lyme disease-carrying ticks is mainly around the home, researchers developed an edge-contrast index that was highly predictive of LD incidence. Their study area comprised significant exurban "sprawl" into previously rural areas of mixed forest and agricultural landcover. Jackson et al. (2006) suggested that higher-density development in these exurban settings, as well as lower interspersion of forest and herbaceous cover at current densities, could reduce LD risk. Adapting this model to other parts of the country will require consideration of

[1] Via entomological risk factors of tick density and rate of tick infection with the Lyme disease pathogen
[2] Community composition and abundance

older, more forested exurban development, and working agricultural landscapes where landowners tend crop or pasture lands.

Landscape Futures and Green Infrastructure

Geographic scale was emphasized as an important factor for assessing LD risk and needs to be considered as part of short and long-term land use planning. Land use planning is typically carried out at the local level, with property rights, taxes, and community benefit at stake. The planning process was described, using a Maine case study, the *Rural Brunswick Smart Growth Project*, as an example of how science was used to inform a multi-stakeholder plan to meet conservation and economic objectives through both regulatory and voluntary measures. Using maps of scientific data on indicator species and habitat blocks and corridors, a plan was implemented to reduce the continuing loss of habitat for native species in rural areas of Brunswick, ME while still accommodating residential development in appropriate areas. Recommendations were made to the research community to make science accessible and acceptable for consideration as a public health benefit in planning, and particularly, to describe how the biodiversity-LD linkages can affect individuals.

Green Infrastructure/Smart Growth (GI/SG) prescribe an integrated network to support ecological and social processes and the benefits they provide to humans. The challenge in GI/SG planning is to build local landscape knowledge and to identify mutual benefits (such as increasing property values and conservation) that will result. "Safe to fail" pilot projects can test new designs – these can include new *transdisciplinary*[3] studies of landscape treatments and LD transmission at multiple scales. Transdisciplinary research is needed to further clarify links between landscape spatial configuration with disease thresholds. Land management strategies needs to include monitoring and be adaptive to change. The cost-effectiveness of different management approaches must be assessed.

The loss of upland and wetland habitats results in loss of ecosystem services upon which humans and natural systems depend; these include, but are not limited to, carbon and nutrient cycling, sediment trapping, biodiversity, and flood/storm mitigation. Since landscape degradation can impact valued ecological resources which EPA is mandated to protect, the agency is taking an active role in landscape conservation and restoration through GI/SG efforts at local, state, and regional levels. Strategic conservation through GI/SG is science-based, proactive, holistic, multifunctional, and may be applied at multiple spatial and temporal scales. One of the critical products of GI/SG planning is the identification of an interconnected network of ecosystems, working landscapes, and clean water necessary to maintain and support healthy ecosystems and the services they provide to humans and nature. In addition to entomological risk factors of LD, ecological factors such as habitat and species composition, distance to tick habitat, and landscape structure should also be considered in land use planning. Managers must know the appropriate temporal and spatial scales to work together to reduce LD risk. For example, in Rhode Island, managers can implement seasonal risk reduction strategies at the state scale, since scientific data show that tick populations are synchronous in their life cycles. Managing LD risk can be one

[3] Where data users work with researchers from the beginning of the research process

benefit from GI/SG strategies, but questions remain about how to plan GI/SG to specifically reduce disease risk, and how to prevent or mitigate possible adverse effects of other disease risks when we encourage animal diversity and movement across habitats. This workshop begins to address in an interdisciplinary way whether we can have dynamic, living landscapes with humans living in them with reduced risk of LD – how managing for biodiversity may result in human health benefits?

Tick Management and Public Health

The reported number of LD cases in Massachusetts (MA) has increased, with 3,350 cases in 2007 and about 4000 cases in 2008, with certain hotspots throughout the state. A bimodal age distribution shows that children and older adults are most affected. While LD is the most significant tick-borne disease problem in MA, babesiosis and anaplasmosis are growing problems, sometimes occurring as co-infections. Effective self-protection behaviors include tucking in pants into socks or shoes, checking for and removing ticks, avoiding wooded areas (preferred nymphal tick habitat), and using repellants.

Integrated tick management allows for a suite of vector control strategies (self-protection, environmental modification, use of area-wide acaricides (chemical agents to eliminate ticks); and where permitted, deer and rodent-targeted acaricides, animal vaccines, natural products, biological control and invasive plant management) for vector control. Well-timed applications of fungus-based biological controls can reduce nymphal tick populations and are being developed for the commercial market. Deer-targeted acaricide treatments delivered by “4-poster” devices are being tested and replicated. As area-wide acaricide applications have relatively low community acceptance, alternatives have been developed. In the laboratory, vaccines targeting animal hosts such as the white-footed mouse, and antibiotics delivered through rodent baits that would eliminate LD infection are being developed and tested in the field. Natural products from tree extracts have been developed as alternatives to synthetic chemical compounds to eliminate tick vectors. These include an Alaska yellow cedar (*Callitropsis nootkatensis*) derivative, nootkatone, which has demonstrated effectiveness against ticks, particularly via high pressure applications in forest plots (Panella et al. 2005). Researchers are identifying other sources of nootkatone (e.g. Furusawa et al. 2005). Work also continues on longer-lasting formulations, and other natural products (garlic-based area-wide repellants) are in development.

Residential landscape management can reduce tick-suitable habitat and peridomestic[4] LD risk (Stafford 2004). Under organic land care standards, preferred practices include clearing brush and leaf litter, putting in landscape barriers, mowing lawns to keep grass length short, pruning low-lying brush, and keeping woodpiles away from the house. Deer exclusion with fencing, natural repellants, and deer-resistant plantings are also advised. Interestingly, LD incidence is high in many states where Japanese barberry, (*Berberis thunbergii*), is reported invasive. There are strong correlations between adult and larval tick abundance and degree of barberry infestation. In Connecticut, managing Japanese barberry infestations has been shown to reduce

[4] Of or pertaining to living in and around human habitations

both tick abundance and the proportion of ticks infected with the LD bacteria (Ward et al. 2009). In southern Maine, black-legged ticks were twice as abundant in barberry invaded coastal woodlands compared to native forests (Elias et al. 2006).

Deer are the preferred animal hosts of adult-stage black-legged ticks. Fragmented habitat and forested areas, along with limited hunting access, contribute to the increasing abundance of deer in urban and suburban landscapes. Massachusetts manages deer populations through a comprehensive regulated harvest strategy relative to regional deer population goals. Due to the state's ability to biologically sample harvested deer, biologists have long-term data necessary for population modeling on a regional basis. In MA, deer management goals are to have a healthy deer population while considering the ecological carrying capacity (habitat limitations) and the cultural carrying capacity (considering recreational hunting and public health and safety). Among these goals, minimizing Lyme disease risk is a recognized public health concern. The deer population in MA is considered to be most effectively and efficiently managed through public hunting. Massachusetts has had some success using hunting to reduce its deer population. The state can modify access, season length, and bag limits. In some areas, reduction in the deer population has been accompanied by reduction in LD incidence; however, in other areas, the deer population has increased beyond the ability of hunting to reduce it significantly enough to affect LD risk. Land use trends and increased interaction between people and the environment will necessitate proactive, concerted management of the white-tailed deer as part of an integrated strategy of LD prevention and control.

Fire Island National Seashore, a protected area, is an illustrative case study of how to integrate techniques to efficiently lower the probability of human exposure to LD. Management programs for vector-borne diseases on protected lands, where conservation of biodiversity is a mandate, are designed to protect public health while minimizing adverse effects on natural systems. The more efficient the management program, the fewer people get sick (public health objective), and the less need for broad scale environmentally damaging interventions (conservation objective). Highly efficient management requires knowledge of both vector ecology and pathogen transmission dynamics to develop accurate surveillance tools and well-targeted control methods. Probabilistic models of pathogen transmission suggest that efficient management requires knowledge of the effects on vector abundance and pathogen prevalence of incremental increases in the level of each intervention. Experimental trials in the field will help determine best practices of effective integrated tick management approaches. Comparison of management strategies should be based on efficacy/cost, efficient integration of methods, applicability, and potential for adverse environmental effects, and any management plan must be adaptive to change. These comparison criteria can be applied to integrated management of ticks in other, non-protected, areas.

Another case study of increasing LD is Nantucket Island. Changes in the fauna (increasing deer population following human introduction, increasing abundance of infected LD ticks), habitat changes (increasing forest, brush and scrub oak thickets), and land use (housing lots located outside of town centers, with deer-attracting plantings) over the last century created favorable conditions for LD emergence and spread. Surveys have revealed public concerns about the effects of LD on quality of life and economic health, with the majority supporting the development of an island-wide plan to reduce the burden of tick-borne diseases. An integrated strategy of public education on self-protection, home landscaping guidance, prevention, and deer reduction was adopted.

Speaker presentations are archived at
http://www.epa.gov/ncer/biodiversity/multimedia/index.html

BREAKOUT GROUP FINDINGS

Information Needs for Integrated Decision-making and Opportunities to Link Environmental Strategies/Models to Public Health

The landscape design community represents an important resource for ideas on how to create less risky landscapes (e.g., plant selection, use of wood chip border areas, not developing into forested areas). It is time for researchers to engage with the land use planning community to share and discuss what is known and what is needed to be able to effectively integrate science into the planning process.

Scale is a very important issue: We should carefully consider how local study results may be generalized to landscape and regional levels, particularly outside of the study area. Data will be needed to inform activities at local and regional levels, and how to apply and implement these data must be clearly communicated to user groups. Beneficiaries of this information include state and local health managers, state and local environmental managers, landscape architects/planners, engineering/design firms, builders, conservation commissions, and planning boards.

Standardized methods of data gathering and reporting as well as common protocols to ensure comparable results are needed.

New community-based, integrated, pilot projects that are "safe to fail" should be developed based on a systems approach. These could include:

- Testing whether different human-occupied landscape "treatments" can be observed and compared over time for differences in LD risk. Transects can be set up at multiple scales (neighborhood, community, county), with choice of scale dependent on study goal.

- Landscape designers could work with scientists to define variables and design transdisciplinary experiments that are replicable and yield statistically valid results.

- Analyzing the landscape features of communities with high rates of LD could determine the utility of these features as management targets for reducing LD risk.

- Using existing landscapes as discrete treatments upon which IPM is implemented - does IPM work better in certain environments, and if so, which are the contributing factors?

Existing research should be synthesized into a summary of previous LD mitigation efforts and their effectiveness (or lack thereof) - this can help guide next steps.

Vector-borne disease mitigation activities require post-implementation monitoring with scientific evaluation.

A better understanding of high and low risk-LD areas can inform people on when (seasonally) and where to take additional self-protection measures. Quantifying the incidence of human disease is crucial.

Education and social/behavioral modification strategies should be included in efforts to mitigate LD risk. Involving the public in the design of their communities can help to communicate the relationship between landscape planning and modification of LD risk. Although public education is common in areas with endemic LD, there are few studies demonstrating its effectiveness.

Providing a toolbox of LD management strategies at the community level would be valuable. Decision-makers identified additional research needs for a toolbox which would enable them to respond to issues of biodiversity/landscape change and vector-borne disease, including:

- research regarding which animal host species will reduce tick abundance and survival;
- research on why tick density and tick infection rates can vary among similar habitats;
- data on the efficacy of natural repellents (e.g., nootkatone preparations) on pets and people;
- research on the effective *application* of tick control treatments, including acaricides and biological-based tools;
- research and evaluation on the feasibility of controlling deer populations in mainland and isolated (e.g. island) populations and its effectiveness at controlling the abundance of infected ticks;
- additional strategies for the LD management toolbox could include more approaches that eliminate the pathogen rather than the host, including antibiotics or a multi-pathogen vaccine for animal hosts; and,
- identifying costs of LD treatment versus prevention, and combining LD cost estimates per case with co-benefits will allow multiple problems to be addressed simultaneously.

Facilitating Collaboration between Researchers and Managers, and among Managers across Disciplines

When research is complete, there needs to be effective communication pathways and products (e.g. a manual of guidelines for towns and landowners, including Land Trusts and other conservation groups) on how to prepare and maintain public access pathways sited in high risk LD areas. A land stewardship or community guide for landscapers and planners could be developed that is reproducible and relevant to communities with various levels of LD risk.

To communicate across disciplines, individuals need to be direct and clear about what they need from each other. Planners and decision-makers often require more certainty than research can provide, and want information more quickly than can be provided, while academics tend to study a topic in more depth than required by planners and decision-makers.

Co-benefits (outcomes) and resource efficiencies can be the basis of incentives to working across disciplines and sectors in cases where collaboration can improve public health environmental outcomes.

Models and examples of Green Infrastructure/Smart Growth (GI/SG) already exist; those which are successful should be adapted and applied more widely. Links between urban planning and epidemiology/ecology should be reinforced, with the aim of demonstrating how GI/SG can make cities and communities more livable. When broad science-based design guidelines for reducing LD risk are available, GI/SG approaches and land use planning can serve as vehicles for implementation.

Communication to the Public

We need to promote a consistent communication message to minimize LD risk while not discouraging outdoor recreation. We need a common message endorsed from various disciplines on how best to assure a healthy, sustainable lifestyle.

Personalizing the topic – what biodiversity-LD linkages will mean to individuals - will help garner political will and deliver an effective public message.

COMMUNITY OF PRACTICE (CoP): NEXT STEPS

The CoP should have multiple but clear goals for communication, information exchange, and research collaboration. A professional support network is needed. EPA can convene meetings to bring together experts in diverse disciplines (also including geographers, social scientists, and landscape architects/planners) to address multiple ways to mitigate LD risk. The value of what has been accomplished at this workshop should be recognized, and an annual meeting may be the most important follow-up action. Future workshops can serve as forums to present updates on scientific research progress, discuss how well research and decision-making needs are aligned, and to discuss how appropriate scientific efforts can be integrated into land-use planning.

Information Resources and Project Development

- Participants involved in this workshop could contribute references and resources to an interactive Web forum/site that provides key background information on each of the related disciplines.
- A charter could be developed to promote the CoP.
- The CoP or CoP partner could issue a call for transdisciplinary research proposals.

- The Workshop Executive Summary should be the first major outreach piece to share findings and attract new CoP partners, particularly in under-represented disciplines (social sciences, landscape architecture/planning).

Communication

- Experts at communicating across disciplines should be encouraged to participate in future meetings. A common language without jargon is needed for successful collaboration across disciplines.

- Communication among different groups with an interest in LD must be increased, through workshops or other means. We should identify a core panel of experts willing to act as liaisons to their respective disciplinary communities – they can facilitate outreach at meetings, and link to new interdisciplinary groups, such as the new Urban Long-Term Research Area (ULTRA)[5]-funded interdisciplinary team which will be engaged in long-term monitoring of human-ecosystem dynamics.

- To find the right balance in communicating with the public and addressing conflicting messages received by the public, it may be necessary to identify points of agreement, be transparent about differences, recognize the different information needs of different groups, and provide broader public education to help contextualize these issues.

Mechanism

- A ready mechanism to facilitate interactions and share information is EPA's web-based Environmental Science Connector (ESC). Participants outside of EPA can join and navigate full functions, including web conferencing.

- Another ready mechanism is a listserve, where information can be exchanged and controversial issues discussed via email.

[5] http://www.nsf.gov/pubs/2009/nsf09551/nsf09551.htm and http://nrs.fs.fed.us/urban/ultra/

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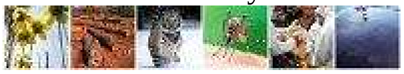


Appendix B. Workshop Presenter Abstracts

Biodiversity and Green Infrastructure: Policies, Strategies and the Need for Interdisciplinary Collaboration

Jack Ahern, PhD, FASLA, Professor of Landscape Architecture and Regional Planning, University of Massachusetts, Amherst, MA

ABSTRACT: Green infrastructure is emerging policy concept to link ecosystem services with the design and construction of many components of the built environment. Green infrastructure has proven effective for managing urban stormwater, for providing recreation and alternative transportation routes. More recently, green infrastructure has been understood and practiced as a strategy to adapt cities to climate change and its consequences. The potential for green infrastructure to address the issue of biodiversity loss, with its consequent impacts on vector-borne disease transmission - largely remains to be addressed through interdisciplinary research and collaborations. Key questions raised and research needed to integrate biodiversity with green infrastructure planning and design include:

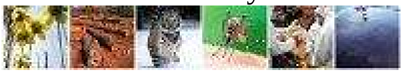
1) Are existing research results linking biodiversity with landscape pattern available/transferable for application to specific land use planning actions in New England?
2) What types of "design experiments" can be conceived to explore and test relationships between green infrastructure, land use/land cover and Lyme disease?
3) What form(s) of monitoring are appropriate to produce locally-relevant causal relationships between landscape configuration and Lyme disease occurrence?

Sustaining Life—Biodiversity and Human Health: An Overview

Eric Chivian, MD, Founder and Director of the Center for Health and the Global Environment, and Assistant Clinical Professor of Psychiatry, Harvard Medical School, Boston, MA

ABSTRACT: Most attention paid to the loss of biodiversity has focused on the expected ecological consequences or on the aesthetic, ethical, sociological, or economic dimensions of this loss for human beings. The implications for our health are rarely considered. This is a serious problem, for not only are the full human impacts of biodiversity loss failing to inform policy decisions, but the public, lacking an understanding of the health risks involved, is not grasping the magnitude of the biodiversity crisis and not developing a sense of urgency about addressing it.

My talk will examine in broad terms the relationship of human health and biodiversity, touching on some case studies of medicines and biomedical research derived from Nature. Special attention will be given to how biodiversity loss, which can change the abundance of, and relationships among, pathogens, vectors, and hosts and the environments in which they live, can affect the outbreak and spread of some human infectious diseases. Because this conference is on Lyme, other models will be considered. Our new Oxford University Press book *Sustaining Life: How Human Health Depends on Biodiversity* will be used to provide the case studies



Managing White-Tailed Deer Populations in Massachusetts

Sonia Christensen, MS, Deer/Moose Project Leader, Massachusetts Division of Fisheries and Wildlife, Westboro, MA

ABSTRACT: The white-tailed deer is a valued native wildlife species found throughout the Commonwealth of Massachusetts. The Division of Fisheries and Wildlife (DFW) manages deer populations through a comprehensive regulated harvest strategy relative to regional deer population goals. Due to the DFW's historic ability to biologically sample harvested deer, biologists have long term data necessary for population modeling on a regional basis. Management goals were established to meet three main objectives: maintain healthy deer populations at levels that are within their ecological carrying capacity; sustain harvest and deer viewing opportunities for hunters and wildlife watchers; and minimize impacts on public health, public safety, and property damage (i.e. prevent them from exceeding cultural carrying capacity). Among these goals, minimizing Lyme disease risk is a recognized public health concern. Studies suggest that the white-tailed deer is a preferred host of the blacklegged tick (*Ixodes dammini*) and that a correlation exists between high deer populations and high tick populations. Thus, the management and research of deer densities in areas known to be endemic to Lyme disease is critical. Furthermore, reduced land access in eastern Massachusetts and the changing demographics of the hunting community create challenges for managing deer populations and, in some instances, deer overabundance. Although most regions in Massachusetts are currently at management goal levels, an increasing deer population will pose a greater likelihood of increasing tick populations. Future landscape level and human dimension changes will necessitate proactive, concerted management of the white-tailed deer.

Public Health Impact of the Further Geographic Spread and Increased Intensity of Risk of Lyme and Other Tickborne Diseases in Massachusetts

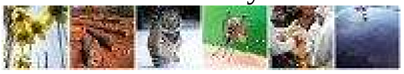
Alfred DeMaria, Jr., MD, Medical Director, State Epidemiologist, Assistant Commissioner, Massachusetts Department of Public Health, Bureau of Infectious Disease Prevention and Response, Jamaica Plain, MA

ABSTRACT: Tickborne diseases are having a greater impact on the public's health and the public health infrastructure in Massachusetts, and the rest of New England. The presenter will review the epidemiology of Lyme disease, babesiosis and anaplasmosis in Massachusetts, and the impact on the population and on local and state public health agencies of inexorable increases in reported tickborne disease over the past 20 years, and will discuss issues that arise related to surveillance, prevention and clinical management controversies.

Climate, Landscape, and Host Community Diversity as Predictors of Lyme Disease Risk at Different Scales in the United States

Maria Diuk-Wasser, PhD, Assistant Professor, Yale School of Public Health, Division of Epidemiology of Microbial Diseases, New Haven, CT

ABSTRACT: Climate and landscape patterns have been proposed as drivers of Lyme disease risk. The most accurate measure of human risk is the density of host-seeking nymphal *Ixodes scapularis* infected with the pathogen, *Borrelia burgdorferi* (entomological risk). Temperature

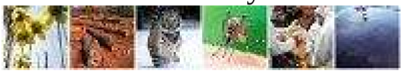


and humidity have been shown to affect tick distribution and density, while landscape patterns have been proposed to determine infection prevalence with *B. burgdorferi*, by affecting the composition and diversity of the host community. We examined environmental predictors of entomological risk in 304 sites located throughout the eastern US and in a more focused study in five sites in northwestern CT, where we also collected data on composition of the host community. A climate-driven predictive model was developed using the nationwide dataset. Although we identified some landscape fragmentation predictors of nymphal infection prevalence, the predictive power was low, mainly due to the very high interannual variability in infection prevalence, which masked spatial effects. Landscape fragmentation, vertebrate host diversity and mouse densities had low predictive power for infection prevalence in the five focal sites, where the range of infection prevalences (0.18 ± 0.08) closely matched that observed in our nationwide sample (0.18 ± 0.12). Our results indicate that, in forested landscapes at a large spatial scale, climate-driven differences in tick densities are the strongest determinants of entomological risk. Most of our study sites were in state parks or other forested areas. Previous studies focusing on forest patch size as a predictor of entomological risk considered patches as isolated units. This assumption is not valid in forested areas, where more complex landscape metrics are needed to describe landscape fragmentation patterns. Studies involving a range of land uses from suburban to closed forest, using a standardized methodology and data analysis, are necessary to provide insights into the factors driving Lyme disease risk in these fundamentally different ecological settings.

Ecological Approaches to Lyme Disease Management on Protected Lands

Howard S. Ginsberg, PhD, Research Ecologist/Field Station Leader, USGS Patuxent Wildlife Research Center, Coastal Field Station, University of Rhode Island, Kingston, RI

ABSTRACT: The relationship between biodiversity and transmission of vector-borne disease is complex and indirect. Management programs for vector-borne diseases on protected lands, where conservation of biodiversity is a mandate, are designed to protect public health while minimizing negative effects on natural systems. The more efficient the management program, the fewer people get sick, and the less the need for broad scale environmentally damaging interventions. Highly efficient management requires knowledge of both vector ecology and pathogen transmission dynamics to develop accurate surveillance tools and well-targeted control methods. Probabilistic models of pathogen transmission suggest that efficient management requires knowledge of the effects on vector abundance and pathogen prevalence of incremental increases in the level of each intervention. Fluctuations in tick numbers have a more or less linear effect on vertebrate disease incidence when tick abundance or spirochete prevalence is low (e.g., on lawns) but not when pathogen prevalence and tick numbers are high (e.g., in woodlands in endemic areas). Therefore, effectiveness of management depends on initial conditions of vector abundance and pathogen prevalence, and interventions that lower incidence of human disease might not similarly affect incidence in wildlife. The structure of the transmission cycle (numbers and phenologies of competent vector and reservoir species) influences growth and stability of local pathogen prevalence. Efficiently integrated and well-targeted management can protect public health while minimizing negative effects on nontarget organisms.



Evaluating Effects of Localized Habitat Manipulations on Landscape-Level Dynamics of White-Footed Mouse Populations

Jason Grear, PhD, Ecologist, EPA, Office of Research and Development, Atlantic Ecology Division, Population Ecology Branch, Narragansett, RI

ABSTRACT: Due to complex population dynamics and migration behaviors, the well-being of animal populations that host human diseases sometimes varies across landscapes in ways that cannot be deduced from geographic abundance patterns alone. In such cases, efficient management of ecological characteristics that control disease prevalence may be difficult to achieve. This presentation describes solutions to this problem using a combination of intensive field-based analyses of demography and migration and spatial matrix models of white-footed mouse populations (*Peromyscus leucopus*). Using landscape-scale field experiments, results of this work show how small-scale habitat manipulations can affect population dynamics over the larger landscape. The presentation also describes the level of effort required to produce this knowledge, in this case through an extramural collaboration, and some of the benefits it provides to the management of disease vector populations.

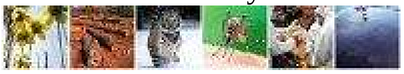
Science-Based Land Use Planning at the Local Level

Theo Holtwijk, MA, Director of Long-Range Planning, Town of Falmouth, Falmouth, ME

ABSTRACT: How can a Town use science to address the continued fragmentation of working woodlots and forest habitats? What other aspects, besides science, have to be kept in mind when undertaking such an effort? These were some of the challenges facing the Town of Brunswick, Maine, a community of 22,000 in Mid-Coast Maine, in 2003 which ultimately resulted in the Rural Brunswick Smart Growth project. This project aimed to reduce the continuing loss of habitat for native species in rural areas, while simultaneously accommodating residential development in those areas. The intent of the project is to minimize the removal of woody vegetation that breaks large unfragmented blocks of forest into smaller patches of forest; and to minimize activities that block or limit species movement between unfragmented blocks of forest

A key element of the project was to define the resource. Utilizing maps from Beginning with Habitat, a habitat conservation program of federal, state and local agencies and non-governmental organizations, aerial photographs and prior assessments, and field work, town staff and consulting ecologists identified priority linkages between habitat blocks based on existing forest cover, frequency of road crossings and density of existing development. From that data, a network of blocks and corridors was identified to focus on, and a multiple set of tools – regulatory, incentive based and voluntary protections – was determined to be most appropriate to accomplish the objective of minimizing future fragmentation pressures in these areas.

Preliminary results: Since the adoption of the regulatory changes in 2005, fragmentation of habitat has been limited and some key habitat areas have been protected. Additionally, having a publicly-endorsed conservation blueprint has enabled the town to be successful in securing significant grant funds to protect additional acres of rural land identified as strategically important for conservation within the Rural Brunswick Smart Growth blocks.



Lessons Learned:

1. Having a diverse steering committee, so concerns could be heard and addressed early on instead of at the Council-review stage of the project.
2. Having a sound scientific method and fieldwork, combined with lot by lot map review, that resulted in habitat maps that were never questioned by the public.
3. Having a balanced carrots and sticks regulatory approach.
4. Being willing to accept modest, additional habitat losses.
5. Crafting limited, but practical exemptions, where needed.
6. Spending the time to meet one on one with property owners to review potential implications for their property and documenting those conversations.
7. Offering a set of recommendations beyond regulatory measures.

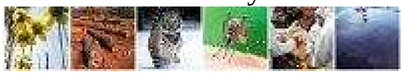
Landscape Fragmentation Model of Lyme Disease in EPA Region 3 and Beyond

Laura Jackson, PhD, Research Biologist, Theme Lead for Human Well-Being, Ecosystem Services Research Program, EPA, Office of Research and Development, Research Triangle Park, NC, and Betsy Hilborn, DVM, MPH, EPA, Office of Research and Development Research Triangle Park, NC

ABSTRACT: Using two landcover pattern metrics and an income variable, we developed a descriptive ecologic model of Lyme disease rates for 514 community landscapes across a 15,000 km^2 area of central Maryland (12 counties plus the City of Baltimore). Maryland represents the southern end of the eastern endemic region for Lyme disease; we selected it due to the availability of high-quality health records, satellite imagery, and comprehensive, electronic land ownership files. The MD Dept. of Health and Mental Hygiene provided address-matched data for 2,137 confirmed Lyme disease cases reported during 1996-2000 from passive surveillance. We quantified landcover pattern metrics using 30-meter Thematic Mapper satellite imagery from 2001; we used major roads to partition the study area into analysis landscapes ranging from 0.002 to 580 km^2. Demographic data came from the 2000 US Census.

The parameter that explained the most variation in incidence rate was the percent of habitat edge represented by forest adjoining lawn and other herbaceous cover ($R^2 = 0.75$; rate ratio = 1.34 [1.26, 1.43], $p < 0.0001$). Also highly significant was percent of the community in forest cover (cumulative $R^2 = 0.82$), which exhibited a quadratic relationship with incidence rate. Modeled relationships applied throughout the range of landscape sizes. Landscapes with approximately fifty percent forest and high forest-herbaceous interspersion had the highest rates of reported Lyme disease.

Previous research has suggested that fragmented forests do not support native predators and competitors of disturbance-tolerant species that are the most competent reservoirs for the bacterial agent of Lyme disease. Therefore, fragmentation may degrade the natural pest regulation service of intact forest ecosystems. An additional explanation for our observed high-risk landcover pattern is the increased human exposure created by residential intrusion into the forest-agricultural matrix now characteristic of much of the rural (exurban) East. Whether one or both processes are responsible, risk reduction may be most effective at the community, rather



than the individual level. New housing options provided through urban and suburban infill, and through clustering and moderate densities in "greenfields," would dampen the proliferation of forest-herbaceous interspersion. Multiple co-benefits accrue to these design alternatives as well.

We are currently validating our Lyme disease study results in Pennsylvania, New York, and Wisconsin to determine the predictive utility of landcover pattern variables across endemic landscapes. Results in PA confirm the significance of forest-herbaceous interspersion under various model structures. Future plans include mapping human Lyme disease risk across part or all of the eastern endemic region, given alternate landscape development scenarios at the Census-tract scale. We also seek to incorporate field data from EPA collaborators into a mechanistic wildlife population distribution model in order to explore the degree to which our forest-herbaceous edge metric is indicating degraded host biodiversity in addition to increased human peridomestic exposure.

Tick Tales of the Grey Lady—Revenge of Old Buck

Timothy Lepore, MD, FACS, Surgeon, Nantucket Cottage Hospital, Nantucket, MA

ABSTRACT: Nantucket Island has an very high incidence of tick borne diseases. This is the consequence of the introduction of white-tailed deer, the arrival of deer ticks and changes in land usage. The community, which swells to 50,000 in the summer from the year round population of 8,000 has reacted to this public health menace in a variety of ways.

Landscape Conservation Through Green Infrastructure Planning: Implications for Lyme Disease

Matt Nicholson, PhD, Landscape Ecologist, EPA Region 3, Philadelphia, PA

ABSTRACT: Lyme disease involves processes that occur over a broad range of scales. While individual human risk often can be mitigated through local scale efforts, recent studies have shown that the dynamics of risk are similar across large scales. This suggests that a landscape approach to managing Lyme disease risk is warranted. However, landuse has historically been managed at the local level and attempts at conservation have often been opportunistic and haphazard; not an effective approach when trying to manage landscape level phenomena. Faced with this challenge, managers have developed an ecosystem-based approach to land conservation, restoration and growth management called Green Infrastructure. One of the critical products of Green Infrastructure planning is the identification of an interconnected network of natural lands, working lands, and waters necessary to maintain and support healthy ecosystem and the services they provide humans. This talk will introduce the concept of Green Infrastructure, and suggest how it may be possible to reduce population-level Lyme disease risk through careful Green Infrastructure Planning.

Mechanisms Linking Host Biodiversity to Lyme Disease Risk

Richard S. Ostfeld, PhD, Senior Scientist, Cary Institute of Ecosystem Studies, Millbrook, NY

ABSTRACT: In eastern and central North America, risk of human exposure to Lyme disease is correlated with the population density of nymphal blacklegged ticks and with the proportion of

nymphal ticks that are infected with the causative agent, *Borrelia burgdorferi.* This talk describes a research program that addresses the ecological factors determining the density and infection prevalence of nymphal ticks in a Lyme disease endemic area of southeastern New York State.

Nymphal infection prevalence. Blacklegged ticks hatch free of *B. burgdorferi*, and infection can only occur via blood meals from reservoir hosts. Larval blacklegged ticks feed from dozens of species of mammals, birds, and reptiles. White-footed mice are the most competent reservoir for *B. burgdorferi*, infecting ~90% of ticks that feed on them. Eastern chipmunks and shrews are moderately efficient reservoirs, and all other hosts infect only a small proportion of feeding ticks. Our surveys of vertebrate biodiversity in northeastern U.S.A. landscapes reveal that white-footed mice are ubiquitous, being common in even the most fragmented and degraded terrestrial habitats, with other vertebrate hosts disappearing as habitats are fragmented. Therefore, high-diversity communities have mice and many other hosts, whereas low-diversity communities have mice and few non-mouse hosts. Nymphal infection prevalence is correspondingly higher in low-diversity communities.

Density of nymphal ticks. Long-term monitoring of tick populations in southeastern New York State reveals that nymph density is not correlated with the prior year's larval density. Instead, the density of nymphs in any given year is determined by survival rate from the larval to the nymphal stage. Larva-to-nymph survival depends on larval encounter rates with hosts, larval success in feeding from hosts, molting success of fed larvae, and overwintering survival of newly molted nymphs. Our recent research has revealed that all of these factors vary depending on the species of host. Larval tick burdens on mice are strongly reduced as the abundance of non-mouse hosts increases. Feeding success of larval ticks is considerably higher on mice than on other hosts. Molting and overwintering success are higher on mice than on most other hosts. Some hosts, notably opossums and gray squirrels, kill hundreds to thousands of larval ticks per hectare via host grooming or supplying an inadequate blood meal. An empirically based simulation model shows that the loss of vertebrate species from host communities can cause a dramatic increase in the density of nymphs.

Biodiversity loss therefore causes an increase in the density and infection prevalence of nymphal ticks by several independent mechanisms. Future research that focuses on the local and landscape variables affecting vertebrate diversity in Lyme disease endemic areas, will be critical for guiding landscape-management efforts to reduce risk.

Lyme Disease Integrated Tick Management and Biodiversity

Joseph Piesman, DSc, Chief, Tick-Borne Diseases Activity Bacterial Diseases Branch, Division of Vector-Borne Infectious Diseases, Centers for Disease Control and Prevention, Fort Collins, CO

ABSTRACT: Devising effective integrated tick management practices for the prevention of Lyme disease requires an extensive knowledge base regarding the transmission cycle of the Lyme disease spirochete. Well timed applications of area-wide acaricides directed at the forest-lawn interface can dramatically lower populations of questing nymphal *I. scapularis*. But,

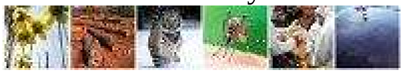
homeowners in suburban neighborhoods in the hyperendemic northeastern United States are reluctant to use traditional chemical acaricides. Area-wide alternatives to chemical acaricides include fungal agents, botanical extracts, soaps, desiccants, as well as vegetation management. Host-targeted approaches have also been developed targeting both rodent hosts of immature ticks and deer, the principal hosts for adult *I. scapularis*. Host-targeted approaches have been shown to reduce the number of questing nymphs infected with Lyme disease spirochetes, but the "plasticity" of the Lyme disease spirochete transmission cycle must be taken into account when these methods are applied on a wide scale.

Regional Vulnerability Assessment and Landscape Futures as a Human Health Tool
Betsy Smith, PhD, EPA, Office of Research and Development, National Exposure Research Laboratory, Research Triangle Park, NC

ABSTRACT: ORD's Regional Vulnerability Assessment (ReVA) Program has been working over the past 11 years to develop methods to make use of existing data and models such that conditions and vulnerabilities can be projected across geographic regions to identify areas and populations (both ecological and human) at highest risk from multiple stresses or where opportunities exist to improve broad-scale environmental conditions. Specific examples of assessing human health vulnerabilities to date include a national mercury assessment, a hazardous air pollutants assessment for the Southeast, and regional assessments incorporating criteria air pollutants. As ORD's Ecosystem Services Research Program moves forward with its new emphasis on human well-being, human health vulnerabilities associated with surface- and ground-water quality, vector-borne diseases, and potentially other ecologically-related issues will be highlighted through alternative future scenarios.

Cultural, Biological, and Natural Tick Control for the Management of Lyme Disease
Kirby C. Stafford III, PhD, Vice Director, Chief Entomologist, State Entomologist, The Connecticut Agricultural Experiment Station, New Haven, CT, and Anuja Bharadwaj, PhD, Postdoctoral Research Scientist, The Connecticut Agricultural Experiment Station, New Haven, CT

ABSTRACT: Lyme disease is primarily as peridomestic disease with approximately 75% of cases acquired from a tick bite around the home. While acaricides can provide effective (68-100%) control of the blacklegged tick, *Ixodes scapularis*, only 21-44% of survey respondents are willing to spray a chemical insecticide. Surveys have found brush and leaf litter control or landscape barriers have a high (82-91%) degree of acceptance and these methods can provide medium (35-77%) levels of control. Controlling Japanese barberry has been shown to significantly reduce tick abundance and the prevalence of the Lyme disease agent, *Borrelia burgdorferi*, in the blacklegged tick. This tick is highly susceptible to the entomopathogenic fungus *Metarhizium anisopliae* Strain 52 in the laboratory and field applications can provide an average of 55 to 85% control in a residential setting. This fungus is under commercial development by Novozymes Biologicals, Ins. (Salem, VA). Nootkatone, an essential oil compound from Alaska yellow cedar and grapefruit, is acaricidal and trials in 2008 and 2009 provided 100% control for several days to weeks, depending on the nootkatone formulation and analysis of nootkatone residues is helping understand the longevity and movement of the



material after application. A garlic-based product appeared to suppress nymphal tick activity for 2-3 weeks. Cultural, biological, and natural control strategies could offer an environmentally acceptable alternative to synthetic chemicals for tick IPM and the management of Lyme disease in the residential landscape.

Appendix C. Workshop Speaker Biographies

Jack Ahern, PhD, FASLA
Professor
Department of Landscape Architecture & Regional Planning
University of Massachusetts, Amherst, MA

Jack Ahern, holds a BS in Environmental Design (Massachusetts), an MLA (Pennsylvania), and a PhD, Environmental Sciences (Wageningen Netherlands). Registered and Fellow of the American Society of Landscape Architects (ASLA), Ahern has received numerous awards for his work in applied landscape ecology and greenways, including a Fulbright Research Fellowship in Portugal, and Honour Awards from the American Society of Landscape Architects and the Boston Society of Landscape Architects for his books and research. His books include: *Measuring Landscapes: A Planner's Handbook* (2006); *Biodiversity Planning and Design: Sustainable Practices* (2006); *Greenways as Strategic Landscape Planning: Theory and Application* (2002); A *Guide to the Landscape Architecture of Boston* (1999); and *Greenways: the Beginning of an International Movement* (1995). His current research focuses on the integration and application of landscape ecology in landscape planning and design, with emphasis on green infrastructure, greenways, and sustainable urbanism—at multiple scales.

John Carroll, PhD
Entomologist
USDA, Agricultural Research Service, Animal Parasitic Diseases
Beltsville, MD

John Carroll conducts research at the Agricultural Research Service—Animal Parasitic Diseases Laboratory in Beltsville, Maryland. ARS is the U.S. Department of Agriculture's chief scientific research agency. Dr. Carroll investigates methods of suppressing populations of the black-legged tick (deer tick), vector of the pathogen causing Lyme disease.

Eric Chivian, MD
Director
Center for Health and the Global Environment, Harvard Medical School
Boston, MA

Dr. Eric Chivian is Founder and Director of the Center for Health and the Global Environment, and an Assistant Clinical Professor of Psychiatry, at Harvard Medical School. In 1980, he co-founded (with Professors Bernard Lown, Herbert Abrams, and James Muller) International Physicians for the Prevention of Nuclear War, recipient of the 1985 Nobel Peace Prize.

During the past 18 years, he has worked to involve physicians in the United States and abroad in efforts to protect the environment, and to increase public understanding of the potential human health consequences of global environmental change. He was senior editor and author of MIT Press' *Critical Condition: Human Health and the Environment*. The book, published in 1993, the first on the subject for a general audience, has been used as a text at several medical schools,

schools of public health, and universities in the United States and abroad. Editions have been published in German, Spanish, Japanese, Chinese, and Persian. This was Dr. Chivian's 2nd book—his first, for which he was senior editor and author, was *Last Aid: The Medical Dimensions of Nuclear War*, published by W.H. Freeman and Company (*Scientific American*) in 1982, which also appeared in German, Italian, and Japanese editions.

In 1996, Dr. Chivian founded and became director of the Center for Health and the Global Environment at Harvard Medical School, the first center at a medical school in the United States focusing on the human health dimensions of global environmental change. The Center (designated an official "Collaborating Center" of the United Nations Environment Programme) developed and directed the Harvard Medical School course *Human Health and Global Environmental Change* (which has been disseminated to 65 other medical schools, colleges, and universities in the United States and abroad), and has held 20 briefings and taught an intensive annual course on the environment and health for the U.S. Congress. See the Center's Web site for more information http://chge.med.harvard.edu/

Dr. Chivian is the editor and lead author, with Dr. Aaron Bernstein, of *Sustaining Life: How Human Health Depends on Biodiversity*, published in June, 2008 by Oxford University Press and co-sponsored by the United Nations Development Programme, the United Nations Environment Programme, the U.N.'s Convention on Biological Diversity, and the International Union for the Conservation of Nature (IUCN). The book, launched at U.N. headquarters and at the Smithsonian Institution, is the most comprehensive report available on the relationship of human health to the health of the living world. It was named "Best Biology Book of 2008" by the *Library Journal*, along with Bert Holldobler's and Edward O. Wilson's book *The Superorganism*.

In 2008, Dr. Chivian was named by *Time Magazine*, along with the Rev. Richard Cizik, Former Vice President for Governmental Affairs of the National Association of Evangelicals, one of the 100 Most Influential People in the World, for their work in organizing scientists and Evangelicals to join together in efforts to protect the global environment.

Dr. Chivian has lectured widely in the United States and abroad, and has appeared on national television and radio and in the print media in numerous countries. He has more than 100 publications.

Sonja Christensen, MS
Deer/Moose Project Leader
Massachusetts Division of Fisheries and Wildlife
Westboro, MA

Sonja Christensen is currently the Deer and Moose Project Leader for the Division of Fisheries and Wildlife. Originally from northern Minnesota, Sonja graduated with a biology degree from Minnesota State University. While completing her undergraduate degree, she worked for the Minnesota Department of Natural Resources as a wildlife biology research intern, focusing on the white-tailed deer. In 2006, Sonja began her Masters research through the Pennsylvania State University Wildlife and Fisheries Science program and the Pennsylvania Cooperative Fish and

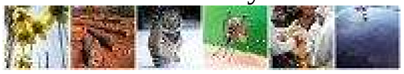
Wildlife Research Unit. Sonja led a research project investigating habitat use, movement, and survival rates of white-tailed deer and exotic sika deer at Assateague Island National Seashore, on Maryland's eastern shore. In April of 2008, while finishing her Masters degree, Sonja accepted the Deer Project Leader position with the Massachusetts Division of Fisheries and Wildlife, where she is currently employed.

Alfred DeMaria, Jr., MD
Medical Director, State Epidemiologist, Assistant Commissioner
Massachusetts Department of Public Health
Bureau of Infectious Disease Prevention and Response
Jamaica Plain, MA

Dr. DeMaria serves as Medical Director of the Bureau of Infectious Disease Prevention, Response and Services in the Massachusetts Department of Public Health. He is also the State Epidemiologist for Massachusetts. He is a graduate of Boston University and Harvard Medical School. He trained in Internal Medicine at Montefiore Medical Center in The Bronx, New York and in Infectious Diseases at Boston City Hospital and the Boston University School of Medicine. Prior to joining the Department of Public Health in 1989, he was an infectious diseases consultant in private practice and prior to that on the staff of The Maxwell Finland Laboratory for Infectious Diseases and Section of Infectious Diseases, Boston City Hospital and Boston University School of Medicine. Dr. DeMaria is a Fellow of the Infectious Diseases Society of America and serves on committees of the Massachusetts Medical Society and the Society for Healthcare Epidemiology of America, and on the boards of the Massachusetts Public Health Association and The Public Health Museum.

Maria Diuk-Wasser, PhD
Assistant Professor
Division of Epidemiology of Microbial Diseases
Yale School of Public Health
New Haven, CT

Maria Diuk-Wasser is interested in modeling the environmental and ecological drivers of vector-borne and zoonotic diseases using intensive field and laboratory-derived data. Under the conceptual framework of landscape epidemiology and using the tools of geographic information systems, remote sensing and spatial statistics, she predicts human disease foci by modeling the distribution of pathogens, vectors and hosts and by examining the environmental drivers of pathogen transmission dynamics, with the ultimate goal of generating spatio-temporal predictions of risk.



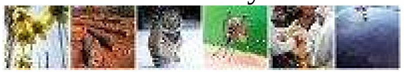
Gary J. Foley, PhD
Director, Executive Office of Earth Observations
Acting Deputy Director
EPA, Office of the Science Advisor
Washington, DC

Dr. Foley currently serves as EPA's Earth Observation Executive in the newly expanded Office of the Science Advisor. In this role, he oversees a team that brings together expertise in measurements, observations, models and decision-support tools and how these bring science into decision-making. Taking this newly formed position in August 2007, Dr. Foley left the position of the Director of the National Center for Environmental Research, where he launched two new exploratory research programs during his two years there. Before that he was the first Director of the National Exposure Research Laboratory beginning in April 30, 1995. Both the Center and the Laboratory are within the Office of Research and Development (ORD) of the U.S. Environmental Protection Agency. For almost two years in 1993-94, he served as the Acting Assistant Administrator for ORD. He has been in ORD for most of his 35 year career at EPA, working within different laboratories and offices on a broad set of environmental research areas focusing on engineering, monitoring, modeling and integrated analysis across the risk paradigm. He has continually been involved in promoting new research approaches, such as integrated modeling, air quality forecasting, sustainability and decision-making, and utilizing the ORD wind tunnel facility to understand complex urban environments. For three years in the late 70's, EPA loaned him to the Organization for Economic Cooperation and Development (OECD) to work on international air pollution, acid rain and energy-environment issues.

He currently chairs the EPA Committee on Regulatory Environmental Modeling. Over the last four years this Committee has developed model use guidelines and a models knowledge data base for EPA. He also serves on the National Academy of Sciences' Chemical Sciences Roundtable which periodically looks at developments in areas like nanotechnology and energy. Internationally, he is the US Co-Chair of the Air Board of the International Joint Commission, doing work on air quality, atmospheric deposition and energy issues in the border region and the Great Lakes for 25 years.

Dr. Foley was appointed as the United States Co-Chair on the User Requirements and Outreach Sub-Group of the *ad hoc* Group on Earth Observations (GEO) in 2003.

Dr. Foley is the recipient of the Meritorious Executive Presidential Rank Award, four EPA Bronze Medals, and six Special Achievement Awards. He received a Bachelor of Science degree from Manhattan College in New York. He holds Master and Doctoral of Science degrees in chemical engineering from the University of Wisconsin.



Howard S. Ginsberg, PhD
Research Ecologist/Field Station Leader
USGS Patuxent Wildlife Research Center, Coastal Field Station,
University of Rhode Island, Kingston, RI

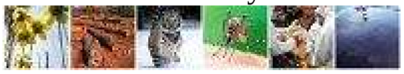
Howard Ginsberg is a Research Ecologist at the USGS Patuxent Wildlife Research Center, and Unit Leader of Patuxent's Coastal Field Station at the University of Rhode Island. He received his PhD in entomology from Cornell University in 1979. Research interests include the ecology of vector-borne diseases, including tick-transmitted infections such as Lyme disease, and mosquito-borne pathogens such as West Nile Virus. His emphasis is on managing vector-borne diseases so as to protect public health, while minimizing negative effects on sensitive natural systems. He is also interested in bee foraging ecology and pollination, especially the interactions between native and introduced species. Dr. Ginsberg received the Director's Award for Natural Resource Research, 1999, from the National Park Service.

Jason Grear, PhD
Ecologist
EPA, Office of Research and Development, Atlantic Ecology Division, Population Ecology Branch
Narragansett, RI

Jason Grear is a research ecologist at ORD's Atlantic Ecology Division in Narragansett, RI. Jason completed his Bachelor's and Master's degrees at Connecticut College and the University of Florida. Prior to his PhD work at Yale's School of Forestry and Environmental Studies, Jason spent six years in Connecticut's coastal management program, where he coordinated Long Island Sound research and coastal habitat restoration. Jason's research areas have included forest stand dynamics, shorebird feeding ecology, spatial dynamics of gregarious animals, bird population dynamics, ecological risk assessment, and most recently the effects of ocean acidification on the population dynamics of marine crustaceans.

Theo Holtwijk, MA
Director of Long-Range Planning, Town of Falmouth
Falmouth, ME

Theo Holtwijk works as Director of Long-Range Planning for the Town of Falmouth, Maine, a small coastal community of about 12,000, just north of Portland, Maine. He hails from The Netherlands and has a Master's degree in Urban and Regional Planning as well as Landscape Architecture. He has worked in the United States since 1985, as a landscape architect for an architecture-engineering firm and as a planner for several municipalities. He also serves as adjunct faculty at the Muskie School of the University of Southern Maine. His work has garnered various awards, including the Rural Brunswick Smart Growth project, which he will discuss at this workshop.



Laura Jackson, PhD
Research Biologist
Theme Lead for Human Well-Being, Ecosystem Services Research Program
EPA, Office of Research and Development
Research Triangle Park, NC

Dr. Laura Jackson is a landscape ecologist with EPA's Office of Research and Development, in Research Triangle Park, North Carolina. She is a Principal Investigator in the Ecosystem Services Research Program, and the program's lead for developing research to link ecosystem services to human health and well-being. Her own work involves the landscape ecology of urbanizing areas and effects of the built environment on ecological and public health. Her record demonstrates a facility for cross-disciplinary synthesis; recent publications have appeared in the International Journal of Epidemiology, Landscape and Urban Planning, Environmental Monitoring and Assessment, and Community Ecology. Dr. Jackson has developed and led research, and performed research management and strategic planning for EPA since 1990. She received her undergraduate degree from Bryn Mawr College, a Master of Environmental Management from Duke University's School of Forestry and Environmental Studies, and a PhD in Ecology at the University of North Carolina at Chapel Hill.

Timothy Lepore, MD, FACS
Surgeon
Nantucket Cottage Hospital
Nantucket, MA

General Surgeon, Resident of Nantucket for 26 years
Tufts Medical School 1970
Surgical residency New England Medical Center 1970-1975
Assistant Professor of Surgery, Brown University Program in Medicine
Medical Director Nantucket Cottage Hospital
Instigator Infamous Nantucket Special Deer Hunting Season

Matt Nicholson, PhD
Landscape Ecologist
EPA, Region 3
Philadelphia, PA

Matt Nicholson is a landscape ecologist with the Environmental Protection Agency's mid-Atlantic Region. Dr. Nicholson received his PhD in Wildlife Ecology from the University of Alaska Fairbanks in 1995. He has experience with the conservation of avian and mammalian species nationally and internationally. The breadth of research he has conducted ranges from human Lyme disease risk through the effects of landscape heterogeneity on the spatial distribution of wildlife. A common theme of his work has involved quantifying spatial patterns in nature and relating them to ecological processes through the use of Geographic Information Systems, remote sensing and other spatial analysis tools. Currently he is leading efforts in the mid-Atlantic Region to demonstrate how EPA Programs can benefit from strategic land conservation through the use of Green Infrastructure planning and assessment.

Richard S. Ostfeld, PhD
Senior Scientist
Cary Institute of Ecosystem Studies
Millbrook, NY

Richard S. Ostfeld is Senior Scientist at the Cary Institute of Ecosystem Studies, a not-for-profit research institution in Millbrook, New York, dedicated to providing the science behind environmental solutions. He is also Adjunct Professor at Rutgers University and the University of Connecticut. His training was at the University of California-Berkeley (PhD) and University of California-Santa Cruz (BA). He has published >150 peer-reviewed articles and co-edited 4 books, including most recently a Princeton University Press volume on Disease Ecology (2008). His research focuses on ecological determinants of human risk of exposure to infectious diseases, emphasizing Lyme and other tick-borne diseases as well as West Nile Virus. His lab group has discovered novel mechanisms by which biodiversity protects human health by reducing rates of pathogen transmission. His research has been covered on National Public Radio (All Things Considered, Life on Earth, and Science Friday), the *New York Times*, *USA Today*, The Associated Press, Reuters, the *Los Angeles Times*, the *Boston Globe*, BBC World Service, Oregon Public Broadcasting, among others. He sits on the editorial boards of *Ecology* and *Vector-borne and Zoonotic Diseases*. Ostfeld has recently established, with William Schlesinger, a new series of scholarly review articles called *The Year in Ecology and Conservation Biology*, which is published under the *Annals of the New York Academy of Sciences* in partnership with Wiley-Blackwell.

Joseph Piesman, DSc
Chief, Tick-Borne Diseases Activity Bacterial Diseases Branch, Division of Vector-Borne Infectious Diseases
Centers for Disease Control and Prevention, Fort Collins, CO

Dr. Piesman is Chief, Tick Borne Disease Activity/Supervisory Microbiologist (Research), Bacterial Diseases Branch, Division of Vector-Borne Infectious Diseases, National Center for Zoonotic, Vector Borne and Enteric Diseases, at the Centers for Disease Control & Prevention. He also serves as Affiliate faculty in the division of Bioagricultural Sciences and Pest Management at Colorado State University. His prior positions include Associate Professor of Epidemiology, School of Public Health, University of Alabama at Birmingham; Assistant Professor of Epidemiology, School of Public Health, UAB; Local Director, International Center for Infectious Disease Research, Salvador, Bahia, Brazil; and, Research Associate, Department of Tropical Public Health, Harvard School of Public Health. Dr. Piesman received his B.S., with Distinction, from Cornell University, and his D.Sc. from Harvard University's School of Public Health, Division of Tropical Public Health. He has produced more than 150 publications in refereed journals.

National Activities: Former Executive Council Member, American Committee on Medical Entomology (Subcommittee of American Society of Tropical Medicine and Hygiene). Past-President, International Northwestern Conference on Diseases in Nature Communicable to Man.
Editorial Activities: Current Editorial Board Member- Tick and Tick Borne Diseases; Former Editorial Board member of Applied & Environmental Microbiology.
Scientific Interests: Medical Entomology, Infectious Diseases, Microbiology, Epidemiology, Biology and Ecology of Lyme Disease, Tick-Borne Diseases, Vector Control.

Betsy Smith, PhD
Regional Vulnerability Assessment (REVA) Program Director
EPA, Office of Research and Development
National Exposure Research Laboratory
Research Triangle Park, NC

Betsy Smith is a senior research ecologist with the National Exposure Research Laboratory in RTP, NC. Dr. Smith received a BS in forestry from The University of the South in 1978, an MS in forest biometrics from the University of Tennessee in 1983, and a PhD in ecology from the University of Tennessee in 1990. Prior to joining EPA, Dr. Smith worked with the Tennessee Valley Authority for 14 years in the areas of regional scale monitoring and assessment, research on air pollution impacts to forests, and landscape analyses. Since 1998, Dr. Smith has served as the director of ORD's Regional Vulnerability Assessment Program (ReVA).

Robert Smith, MD, MPH
Principal Investigator
Vector-borne Disease Laboratory, Maine Medical Center Research Institute
Scarborough, ME

Rob Smith is director of the Infectious Disease fellowship program at Maine Medical Center and co-directs the Vector-Borne Disease Laboratory at the Maine Medical Center Research Institute in Portland. A major focus of the lab, which was established in 1988, is the determination of ecologic factors that impact the emergence of tick-borne diseases in northern New England, and the development and testing of strategies for their prevention and control. Current research interests also include the use of molecular epidemiology to better understand mechanisms of disease emergence and maintenance. Rob has served as a member of Maine's Vector-Borne Disease Work Group since its inception. He is a Fellow of the Infectious Disease Society of America and Clinical Professor of Medicine at the University of Vermont College of Medicine.

Kirby C. Stafford III, PhD
Vice Director, Chief Entomologist, State Entomologist
Department of Entomology
The Connecticut Agricultural Experiment Station
New Haven, CT

Dr. Kirby C. Stafford III is Vice Director of the Connecticut Agricultural Experiment Station, Chief Entomologist (Head) of the Department of Entomology and State Entomologist. He joined the Experiment Station in 1987. His research area is the ecology and control of the blacklegged tick, *Ixodes scapularis,* with a recent focus on natural and biological tick control. Dr. Stafford has authored or co-authored 52 articles in peer reviewed scientific journals, has review chapters on tick management in two books, and produced a Tick Management Handbook. Prior to coming to Connecticut, Dr. Stafford worked at Penn State University on an integrated poultry pest management program. Dr. Stafford obtained his PhD in medical-veterinary entomology from Texas A&M University in 1985, where he also taught veterinary entomology in the Department of Entomology and College of Veterinary Medicine at Texas A&M University. Dr. Stafford received a Master of Science degree in entomology at Kansas State University, and a Bachelor of Science degree in entomology at Colorado State University.

Appendix D. Breakout Reports

Theme 1: Identifying Information Needs for Integrated Decision-making

What information do you need to make credible decisions regarding biodiversity/landscape change and vector-borne (e.g. Lyme) disease as an integrated practice in your profession?

- How can we better focus on integration of biodiversity/landscape change, disease prevention and human health promotion at the local, regional and state levels?
- What has and hasn't worked well in the past?

Analyzing how landscape features have changed over time and how these changes have affected vector-borne disease transmission and spread will help inform future activities. Scale is a very important issue. We should carefully consider how local study results may be generalized to landscape and regional levels, particularly outside of the study area. Data will be needed to inform activities at local and regional levels, and how to apply and implement these data must be clearly communicated to user groups. Beneficiaries of this information include landscape architects/planners, engineering/design firms, builders, conservation commissions, and planning boards. Post-implementation monitoring with scientific evaluation is needed to understand the effects of vector-borne disease mitigation activities. Quantifying the incidence of human disease is crucial, although gathering the necessary information can be difficult. A summary of previous mitigation efforts and their effectiveness (or lack thereof) can help determine necessary next steps.

We need to promote a consistent communication message to people to minimize LD risk while not discouraging outdoor recreation. A better understanding of high and low risk areas can inform people on when (seasonally) and where to take additional self-protection measures.

Theme 2: How to integrate information sharing and decision-making

How can working groups in disciplines like natural resources, human health, urban and regional planning and agriculture better promote human and ecological health?

- What are organizational/institutional incentives to working across disciplines and sectors for the LD problem?
- What are some current impediments to integrating landscape and human health across disciplines and how might they be lessened?
- What has and hasn't worked well in the past?

To communicate across disciplines, individuals need to be direct and clear about what they need from each other. Planners and decision-makers often require more certainty than research can provide, and want information more quickly than can be provided, while academics tend to study a topic in more depth than required by planners and decision-makers. Co-benefits (outcomes) and resource efficiencies can be the basis of incentives to working across disciplines and sectors in cases where collaboration can improve public health environmental outcomes. Standardized methods of data gathering and reporting as well as common protocols to ensure comparable results are needed. Models and examples of Green Infrastructure/Smart Growth (GI/SG) already exist; those which are successful should be adapted and applied more widely. Links between urban planning and epidemiology/ecology should be reinforced, with the aim of demonstrating how GI/SG can make cities and communities more livable.

There is a tendency to jump to outreach prematurely. Effective outreach requires political will, coordination of messages to the public, and recognition of cultural and institutional changes necessary for collaboration. Personalizing the topic will help garner political will and deliver an effective message to the public.

Theme 3: Linking new or existing environmental strategies/models to public health

In what ways could new environmental interventions or ecologically-based approaches, such as Integrated Pest Management (IPM), Green Infrastructure, Smart Growth and Low Impact Development (LID), Regional Vulnerability Assessment (ReVA), complement existing management tools for enhancing landscape health and controlling vector-borne diseases, such as Lyme disease?

- What relevant models and sound examples of ecologically based approaches to landscape/human health can we build on at the state, regional and local levels?

- Is it possible to implement longer term solutions given the political and social urgency of the problems and the multitude of causal factors/drivers (e.g. landscape fragmentation, climate change, eutrophication, etc)?

The group discussed whether we can have dynamic, functioning landscapes while still living in them with reduced risk of LD? Broad, science-based design guidelines are not yet available, but GI/SG approaches and land use planning can serve as vehicles for implementation when tools are ready. The landscape design community represents an important resource for ideas on ways to create less risky landscapes (e.g., plant selection, use of wood chip border areas, not developing into forested areas). Although there is currently insufficient experimental evidence, the time is ripe for researchers to engage with the land use planning community to share what is known and what is needed to be able to effectively integrate science into the planning process.

Determining the primary risk factors for LD risk is difficult because most scientific studies assess one variable at a time and therefore cannot fully analyze interactions among them. Many tick-based studies are not replicated, and existing studies have limited generalizability. Transdisciplinary, “safe to fail” pilot studies can be designed to test whether different human-occupied landscape “treatments” can be observed and compared over time for differences in LD risk. Transects can be set up at multiple scales (neighborhood, community, county). Choice of scale depends on the goal of the study. If protecting ecosystems is the goal, the landscape scale (habitat patches and the connections between them) needs to be included. Complexity increases with scale. Landscape designers could work with scientists to define variables and design transdisciplinary experiments that are replicable and yield statistically valid results. Possible adverse impacts of managing for biodiversity using GI/SG approaches should also be considered.

- Another study could use existing landscapes as discrete treatments upon which IPM is implemented. Does IPM work better in certain environments, and if so, which are the contributing factors?

- Partnering with nonprofits and municipalities with high rates of LD should be considered. Analyzing the landscape features of communities with high rates of LD could determine the utility of these features and help inform future experiments.

- Long term, broad-scale experiments that transect across different densities of forest areas and people should be designed. Assistance could be sought from experts skilled in monitoring systems over long time periods. Larger scale experiments could help determine whether maintaining diverse ecosystems reduces LD risk.

Education and social/behavioral modifications should be included in efforts to mitigate LD risk. High to low risk areas need to be identified and information on them made relevant at the individual-level. Involving the public in the design of their communities can help to communicate the relationship between landscape planning and modification and LD risk. Although public education is common in areas with endemic LD, there are few studies demonstrating its effectiveness.

Theme 4: Identifying research that is useful to decision-makers and managers

What kinds of products from recently completed, ongoing and possible future research might be considered most useful to the public and decision makers at state, regional and local levels to respond to issues of biodiversity/landscape change and vector-borne disease? Please provide examples.

- What are possible, future cooperative research opportunities between academics, EPA, and other Federal, State, Tribal and non-governmental agencies in the area of biodiversity/landscape change and human health?

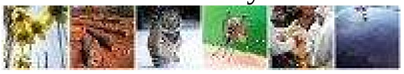
The long time periods over which ecological change occurs must be communicated clearly and in the context of competing interests. A variety of solutions to reducing LD risk will be needed since not every solution will appeal to every group. We need a common message endorsed from various disciplines on how best to assure a healthy, sustainable lifestyle.

New community-based, integrated, pilot projects that are “safe to fail” should be developed based on a systems approach. At the same time, existing research should be synthesized. A literature review evaluating potential linkages between previous study methods and results could help determine the true efficacy of previously implemented practices. From the points of view of decision-makers and managers, the group identified the following research needs:

- research regarding which animal host species will reduce tick abundance and survival;

- research on why tick density and tick infection rates can vary among similar habitats;
- field research on the diversity (composition, abundance) of animal hosts along a fragmentation gradient;
- research on the food web effects of removing ticks from the local environment;
- data on the efficacy of natural repellents (e.g., nootkatone preparations) on pets and people;
- research on the effective *application* of tick control treatments, including acaricides and biological-based tools;
- research and evaluation on the feasibility of controlling deer populations in mainland and isolated (e.g. island) populations and its effectiveness at controlling the abundance of infected ticks, including through deer contraception and application of acaricidal treatments, for example, using "4-poster" devices;
- determination of the transfer rate of LD from household pets to the home, as well as the probability of contracting LD from pet exposure compared to other routes;
- identifying cost equivalents of LD treatment versus prevention and combining LD cost estimates/case with co-benefits will allow multiple problems to be addressed simultaneously; and,
- additional strategies for the LD management toolbox could include more approaches that eliminate the pathogen rather than the host, including antibiotics or a multi-pathogen vaccine for animal hosts.

When research is complete, there needs to be effective communication pathways and products (e.g. a manual of guidelines for towns and landowners, including Land Trusts and other conservation groups) on how to prepare and maintain public access pathways sited in high risk LD areas. A land stewardship or community guide for landscapers and planners could be developed that is reproducible and applicable to communities with various levels of LD risk. Providing a toolbox of LD management strategies at the community level would be valuable.



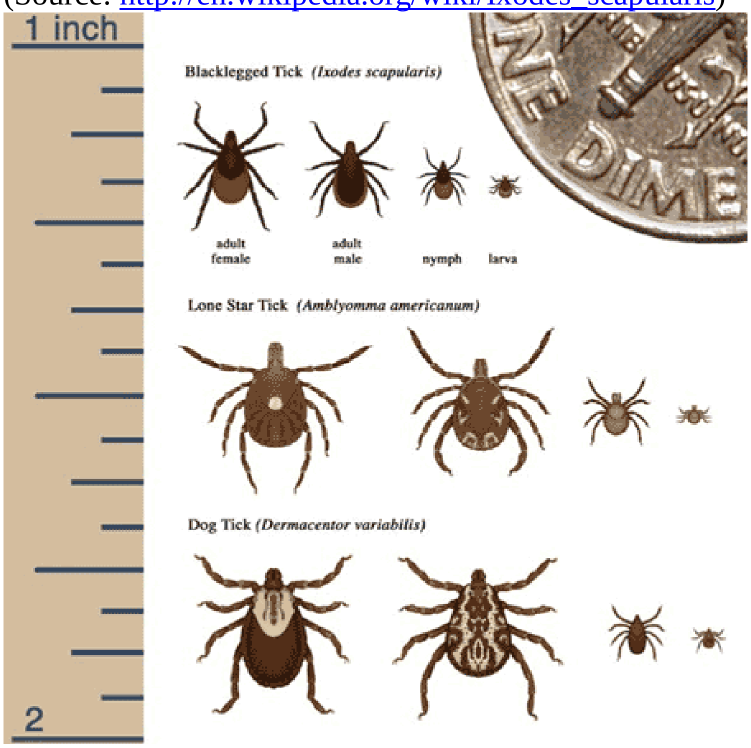
Appendix E. Glossary of Terms and Concepts

Biodiversity

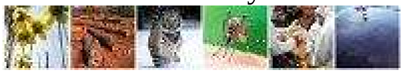
"Biological diversity (sometimes shortened to biodiversity): The variability among living organisms from all sources, including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (Convention on Biological Diversity or CBD, article 2). More generally, the totality of genes, species and ecosystems in a particular region or the world." (Source: http://www.ecoagriculture.org/page.php?id=65&name=Glossary)

Black-legged Tick (*Ixodes scapularis*)

"*Ixodes scapularis*, commonly known as the deer tick or blacklegged tick (although some people reserve the latter term for *Ixodes pacificus*, which is found on the West Coast of the USA), and in some parts of the USA as the bear tick, is a hard-bodied tick (family Ixodidae) of the eastern and northern Midwestern United States. It is a vector for several diseases of animals and humans (e.g., Lyme disease, babesiosis, anaplasmosis, etc). They are known as the deer tick due to their habit of parasitizing the white-tailed deer."
(Source: http://en.wikipedia.org/wiki/Ixodes_scapularis)



Comparative Images of Black-legged, Lone Star and Dog Ticks Source: http://www.cdc.gov/ncidod/dvbid/lyme/ld_blackleggedTick.htm)



Community of Practice

“Communities of practice are formed by people who engage in a process of collective learning in a shared domain of human endeavor: a tribe learning to survive, a band of artists seeking new forms of expression, a group of engineers working on similar problems, a clique of pupils defining their identity in the school, a network of surgeons exploring novel techniques, a gathering of first-time managers helping each other cope. In a nutshell:

> Communities of practice are groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly.

Note that this definition allows for, but does not assume, intentionality: learning can be the reason the community comes together or an incidental outcome of member's interactions. Not everything called a community is a community of practice. A neighborhood for instance, is often called a community, but is usually not a community of practice. Three characteristics are crucial:

1. ***The domain:***

   A community of practice is not merely a club of friends or a network of connections between people. It has an identity defined by a shared domain of interest. Membership therefore implies a commitment to the domain, and therefore a shared competence that distinguishes members from other people. (You could belong to the same network as someone and never know it.) The domain is not necessarily something recognized as "expertise" outside the community. A youth gang may have developed all sorts of ways of dealing with their domain: surviving on the street and maintaining some kind of identity they can live with. They value their collective competence and learn from each other, even though few people outside the group may value or even recognize their expertise.

2. ***The community:***

   In pursuing their interest in their domain, members engage in joint activities and discussions, help each other, and share information. They build relationships that enable them to learn from each other. A website in itself is not a community of practice. Having the same job or the same title does not make for a community of practice unless members interact and learn together. The claims processors in a large insurance company or students in American high schools may have much in common, yet unless they interact and learn together, they do not form a community of practice. But members of a community of practice do not necessarily work together on a daily basis. The Impressionists, for instance, used to meet in cafes and studios to discuss the style of painting they were inventing together. These interactions were essential to making them a community of practice even though they often painted alone.

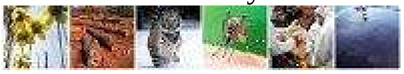
3. The practice:

A community of practice is not merely a community of interest--people who like certain kinds of movies, for instance. Members of a community of practice are practitioners. They develop a shared repertoire of resources: experiences, stories, tools, ways of addressing recurring problems—in short a shared practice. This takes time and sustained interaction. A good conversation with a stranger on an airplane may give you all sorts of interesting insights, but it does not in itself make for a community of practice. The development of a shared practice may be more or less self-conscious. The "windshield wipers" engineers at an auto manufacturer make a concerted effort to collect and document the tricks and lessons they have learned into a knowledge base. By contrast, nurses who meet regularly for lunch in a hospital cafeteria may not realize that their lunch discussions are one of their main sources of knowledge about how to care for patients. Still, in the course of all these conversations, they have developed a set of stories and cases that have become a shared repertoire for their practice.

It is the combination of these three elements that constitutes a community of practice. And it is by developing these three elements in parallel that one cultivates such a community." (Source:

Ecosystem Services
"The benefits that people obtain from ecosystems. These benefits may be environmental, social, or economic. Examples of environmental outcomes include the protection of streams, reduced stormwater runoff, reduced ozone concentrations, and increased carbon sequestration. Social outcomes may include improved human health, buffers for wind and noise, increased recreational opportunities, and neighborhood beautification. Economic outcomes can include reduced heating and cooling costs and increased property values"
(Source: http://www.nrs.fs.fed.us/urban/utc/about/glossary/)

Green Building
Green building is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort. Green building is also known as a sustainable or high performance building. Green buildings are designed to reduce the overall impact of the built environment on human health and the natural environment by efficiently using energy, water, and other resources; protecting occupant health and improving employee productivity; and, reducing waste, pollution and environmental degradation. For example, green buildings may incorporate sustainable materials in their construction e.g., reused, recycled-content, or made from renewable resources); create healthy indoor environments with minimal pollutants (e.g., reduced product emissions); and/or feature landscaping that reduces water usage (e.g., by using native plants that survive without extra watering).
(Source: http://www.epa.gov/greenbuilding/pubs/about.htm)



Green Infrastructure (see also Low Impact Development)

Green infrastructure is an approach to wet weather management that is cost-effective, sustainable, and environmentally friendly. Green Infrastructure management approaches and technologies infiltrate, evapotranspire, capture and reuse stormwater to maintain or restore natural hydrologies. At the largest scale, the preservation and restoration of natural landscape features (such as forests, floodplains and wetlands) are critical components of green stormwater infrastructure. By protecting these ecologically sensitive areas, communities can improve water quality while providing wildlife habitat and opportunities for outdoor recreation. On a smaller scale, green infrastructure practices include rain gardens, porous pavements, green roofs, infiltration planters, trees and tree boxes, and rainwater harvesting for non-potable uses such as toilet flushing and landscape irrigation.
(Source: EPA website (http://cfpub.epa.gov/npdes/home.cfm?program_id=298)

"An adaptable term used to describe an array of products, technologies, and practices that use natural systems – or engineered systems that mimic natural processes – to enhance overall environmental quality and provide utility services. As a general principal, Green Infrastructure techniques use soils and vegetation to infiltrate, evapotranspirate or recycle stormwater runoff."
Source: http://www.epa.gov/greeningepa/glossary.htm)

"Green Infrastructure is a concept originating in the United States in the mid-1990s that highlights the importance of the natural environment in decisions about land use planning. In particular there is an emphasis on the "life support" functions provided by a network of natural ecosystems, with an emphasis on interconnectivity to support long term sustainability. Examples include clean water and healthy soils, as well as the more anthropocentric functions such as recreation and providing shade and shelter in and around towns and cities.

The United States Environmental Protection Agency (EPA) has extended the concept to apply to the management of stormwater runoff at the local level through the use of natural systems, or engineered systems that mimic natural systems, to treat polluted runoff. This use of the term "green infrastructure" to refer to urban "green" best management practices (BMPs), although not central to the larger concept, does contribute to the over health of natural ecosystems."
(Source: http://en.wikipedia.org/wiki/Green_infrastructure; accessed October 28, 2009)

Integrated Pest Management

Integrated Pest Management (IPM) is an effective and environmentally sensitive approach to pest management that relies on a combination of common-sense practices. IPM programs use current, comprehensive information on the life cycles of pests and their interaction with the environment. This information, in combination with available pest control methods, is used to manage pest damage by the most economical means, and with the least possible hazard to people, property, and the environment.

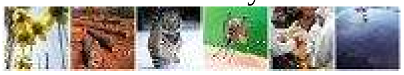
The IPM approach can be applied to both agricultural and non-agricultural settings, such as the home, garden, and workplace. IPM takes advantage of all appropriate pest management options including, but not limited to, the judicious use of pesticides. In contrast, organic food production

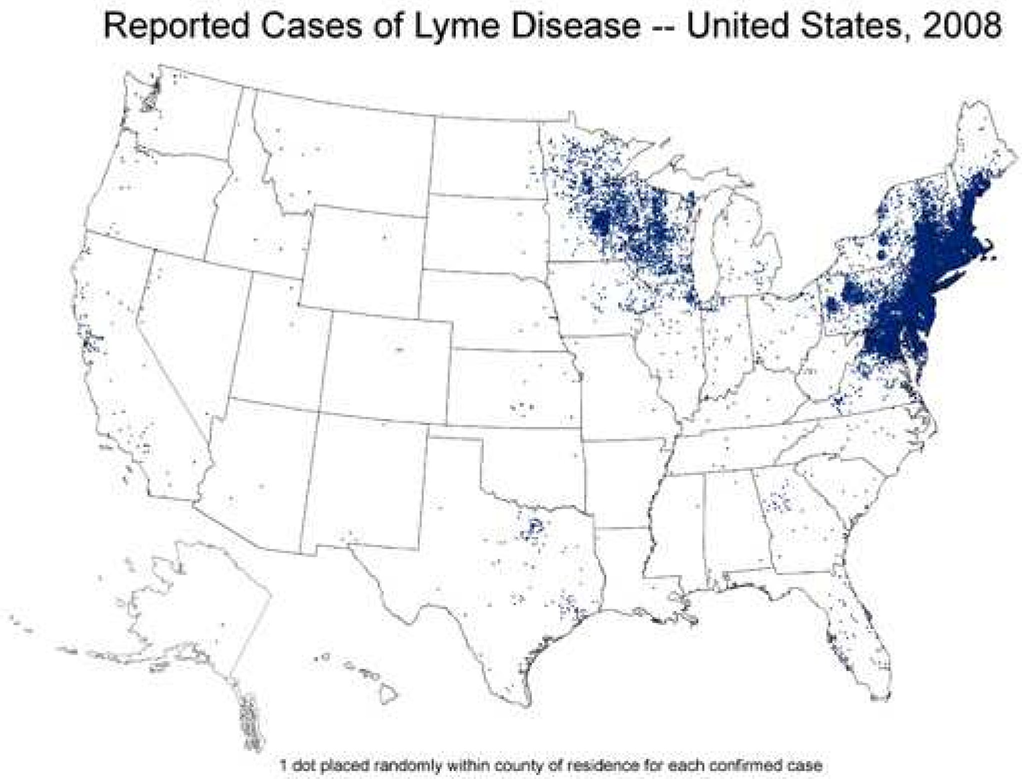
applies many of the same concepts as IPM but limits the use of pesticides to those that are produced from natural sources, as opposed to synthetic chemicals."
(Source: http://www.epa.gov/pesticides/factsheets/ipm.htm)

Land Use Planning
Land use planning guides long-term development or conservation of an area and the establishment of a relationship between local objectives and regional goals. Land-use planning is often guided by laws and regulations. The major instrument for current land-use planning is the establishment of zones that divide an area into districts which are subject to specified regulations. Although land-use planning is sometimes done by private property owners, the term usually refers to permitting by government agencies. Land-use planning is conducted at a variety of scales, from plans by local city governments to regulations by federal agencies. The United States has never developed a national land-use plan because land use is considered a local concern. A major part of local planning is zoning, the division of areas into districts. Zones cover most potential uses, such as residential, commercial, light industry, heavy industry, open space, or transportation infrastructure (such as rail lines or highways). Detailed regulations guide how each zone can be used. As a result of pressures from rapid growth, some cities have begun to write growth management plans that limit the pace of growth. Comprehensive city plans aimed to limit the pace of growth have been accepted by the courts.
(Source: http://www.answers.com/topic/land-use-planning)

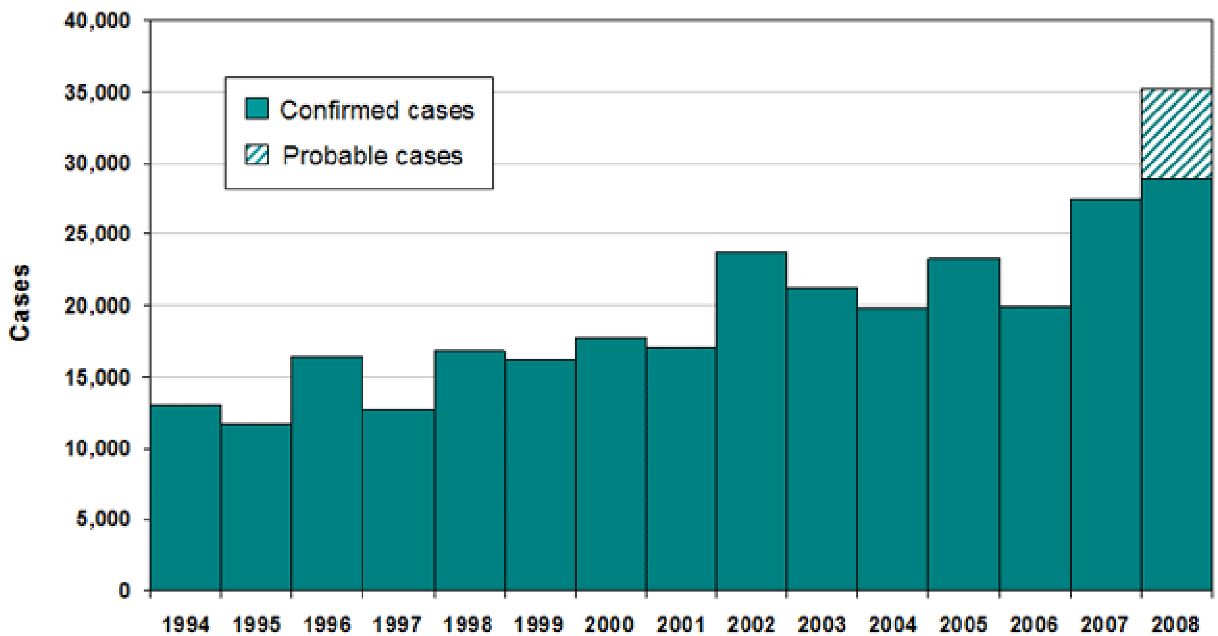
Low Impact Development (see also Green Infrastructure)
LID is an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible. LID employs principles such as preserving and recreating natural landscape features, minimizing effective imperviousness to create functional and appealing site drainage that treat stormwater as a resource rather than a waste product. There are many practices that have been used to adhere to these principles such as bioretention facilities, rain gardens, vegetated rooftops, rain barrels, and permeable pavements. By implementing LID principles and practices, water can be managed in a way that reduces the impact of built areas and promotes the natural movement of water within an ecosystem or watershed. Applied on a broad scale, LID can maintain or restore a watershed's hydrologic and ecological functions.
(Source: http://www.epa.gov/owow/nps/lid/)

Lyme Disease
"A tick-transmitted inflammatory disorder that begins with a characteristic skin rash, and may be followed weeks to months later by neurologic, cardiac, or joint abnormalities."
(Source: http://www.cdc.gov/cfs/cfsglossary.htm#L)





(Source: http://www.cdc.gov/ncidod/dvbid/lyme/ld_Incidence.htm)



Reported Cases of Lyme Disease by Year, United States, 1994-2008
(Source: http://www.cdc.gov/ncidod/dvbid/lyme/ld_UpClimbLymeDis.htm)

Peridomestic
"Of or pertaining to living in and around human habitations."
(Source: http://en.wiktionary.org/wiki/peridomestic)

Regional Vulnerability Assessment (ReVA)
"The Regional Vulnerability Assessment (ReVA) program conducts research on innovative approaches to the evaluation and integration of large and complex datasets and models to assess current conditions and likely outcomes of environmental decisions, including alternative futures.

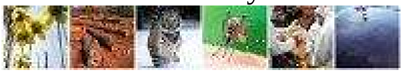
ReVA works with select client groups to develop applied research demonstrations that combine and apply current data and appropriate models across a geographic region. The goals are to interpret current conditions, anticipate future issues, set management and ecosystem protection priorities, and proactively assess decisions that may impact multiple outcomes or involve tradeoffs in a transparent, defensible fashion."
(Source: www.epa.gov/reva; accessed 10/28/09)

Smart Growth
Smart growth covers a range of development and conservation strategies that help protect our natural environment and make our communities more attractive, economically stronger, and more socially diverse. Based on the experience of communities around the nation that have used smart growth approaches to create and maintain great neighborhoods, the Smart Growth Network developed a set of ten basic principles:

1. Mix land uses
2. Take advantage of compact building design
3. Create a range of housing opportunities and choices
4. Create walkable neighborhoods
5. Foster distinctive, attractive communities with a strong sense of place
6. Preserve open space, farmland, natural beauty, and critical environmental areas
7. Strengthen and direct development towards existing communities
8. Provide a variety of transportation choices
9. Make development decisions predictable, fair, and cost effective
10. Encourage community and stakeholder collaboration in development decisions

(Source: http://www.epa.gov/smartgrowth/basic_info.htm)

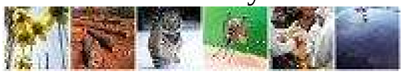
Sustainable Development/Sustainability
The most widely quoted definition internationally is the "Brundtland definition" of the 1987 Report of the World Commission on Environment and Development – that sustainability means "meeting the needs of the present without compromising the ability of future generations to meet their own needs."
(Source: http://www.epa.gov/Sustainability/basicinfo.htm#sustainability)



Urban Long-Term Research Area (ULTRA) Exploratory Awards (ULTRA-Ex)
"The Urban Long-Term Research Areas: Exploratory Research Projects (ULTRA-Ex) competition will provide support to enable teams of scientists and practitioners to conduct interdisciplinary research on the dynamic interactions between people and natural ecosystems in urban settings in ways that will advance both fundamental and applied knowledge."
(Source: http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503283)

Vector-Borne Disease
A disease associated with a pathogen commonly transmitted to humans through vectors (any animal that transmits the pathogen or plays an essential role in the pathogen's life cycle).

Zoonotic Disease
A disease that can be transmitted from animals to people or, more specifically, a human disease associated with a pathogen that normally exists in animals but can infect humans.



Appendix F. Participants List (in person and via webinar)

Jack Ahern, PhD, FASLA (Speaker)
Professor
Department of Landscape Architecture and Regional Planning
University of Massachusetts, Amherst
jfa@larp.umass.edu
http://www.people.umass.edu/jfa/
(413) 545-6632

Bethany Atkins (webinar)
bethany.atkins@maine.gov

Kate Berger (webinar)
kberger19@gmail.com

Anuja Bharadwaj, PhD (Speaker)
Agricultural Postdoctoral Scientist
Department of Entomology
Connecticut Agricultural Experiment Station
anuja.bharadwaj@ct.gov
http://www.ct.gov/CAES/
(203) 974-8470

Catherine M. Brown, DVM, MSc, MPH
State Public Health Veterinarian and Zoonosis Lead
Massachusetts Department of Public Health
catherine.brown@state.ma.us
www.mass.gov/dph/
617-983-6800 (Genl.)

Kathy Campbell (Workshop Organizer)
New England Regional Laboratory
U.S. Environmental Protection Agency
campbell.kathy@epa.gov
(617) 918-8352

John Carroll, PhD (Speaker)
Research Entomologist
U.S. Department of Agriculture
Agricultural Research Service
jcarroll@anri.barc.usda.gov
http://www.ars.usda.gov/main/main.htm
(301) 504-9017

Eric Chivian, MD (Speaker)
Founder and Director
Center for Health and the Global Environment
Assistant Clinical Professor of Psychiatry
Harvard Medical School
eric_chivian@hms.harvard.edu
http://chge.med.harvard.edu/
(617) 384-8536

Sonja Christensen, MS (Speaker)
Deer/Moose Project Leader
Massachusetts Division of Fisheries and Wildlife
sonja.christensen@state.ma.us
http://www.mass.gov/dfwele/dfw/
(508) 389-6320

Marvin Cling
Environmental Specialist
Pleasant Point Reservation
Passamaquoddy Tribe of Indians
marvincling@hotmail.com
http://www.wabanaki.com/index.html
(207) 853-2600

Nora Conlon, PhD (Facilitator)
Quality Assurance Unit
New England Regional Laboratory
U.S. Environmental Protection Agency
conlon.nora@epa.gov
(617) 918-8335

Christina Czarnecki (webinar)
c.czarnecki@unh.edu
(603) 862-2639

Alfred DeMaria, Jr., MD (Speaker)
Medical Director, State Epidemiologist, Assistant Commissioner
Massachusetts Department of Public Health
Bureau of Infectious Disease Prevention and Response
alfred.demaria@state.ma.us
www.mass.gov/dph/
(617) 983-6550

Jodie A. Dionne-Odom, MD
Deputy State Epidemiologist
Division of Public Health Services
Department of Health and Human Services
jodie.dionne-odom@dhhs.state.nh.us
www.dhhs.state.**nh**.us/
(603) 271 1770

Maria Diuk-Wasser, PhD (Speaker)
Assistant Professor
Division of Epidemiology of Microbial Diseases
Yale School of Public Health
maria.diuk@yale.edu
www.med.yale.edu/eph/faculty/wasser.html
(203) 785-4434

Elizabeth Dykstra (webinar)
elizabeth.dykstra@doh.wa.gov

Susan P. Elias (webinar)
Clinical Research Associate
Vector-Borne Disease Laboratory
Maine Medical Center Research Institute
eliass@mmc.org
(207) 662-4506

Gary Fish (webinar)
Manager, Pesticide Programs
Board of Pesticide Control
Maine Department of Agriculture, Food, and Rural Resources
gary.fish@maine.gov
www.maine.gov/agriculture/pesticides/
(207) 287-2731

Gary Foley, PhD (Speaker)
Director of the Executive Office of Earth Observations (EOEO)
Office of the Science Advisor
U.S. Environmental Protection Agency
foley.gary@epa.gov
http://www.epa.gov/osa/index.htm
(919) 541-0711

Trish Garrigan
Environmental Scientist
Region 1
U.S. Environmental Protection Agency
garrigan.trish@epa.gov
(617) 918-1583

Cary Giguere
Section Chief
Vermont Pesticide Program
Agrichemical Management Section
cary.giguere@state.vt.us
http://www.vermontagriculture.com/ARMES/am/pesticide.html
(802) 828-6531

Howard S. Ginsburg, PhD (Speaker)
Research Ecologist/Field Station Leader
USGS Patuxent Wildlife Research Center
Coastal Field Station
University of Rhode Island
hginsberg@usgs.gov
http://www.pwrc.usgs.gov/staff/profiles/documents/ginsberg.htm
(401) 874-4537

Jason Grear, PhD (Speaker)
Ecologist
Population Ecology Branch
Atlantic Ecology Division
Office of Research and Development
U.S. Environmental Protection Agency
grear.jason@epa.gov
http://www.epa.gov/aed/html/peb.html
(401) 782-9615

Julie Hargrave (webinar)
jhargrave@pb.state.ny.us

Greg Hellyer, (Workshop Organizer)
Environmental Scientist
Ecosystem Assessment Unit
New England Regional Laboratory
U.S. Environmental Protection Agency – Region 1
hellyer.greg@epa.gov
www.epa.gov/ne/lab
(617) 918-8677

Robert Hillger, PE (Workshop Organizer)
Senior Science Advisor and Regional/ORD Science Liaison
U.S. Environmental Protection Agency – Region 1
hillger.robert@epa.gov
(617) 918-8660

Jeff Hollister, PhD
Landscape Ecologist
Atlantic Ecology Division
Office of Research and Development
U.S. Environmental Protection Agency
hollister.jeff@epa.gov
http://www.epa.gov/aed/html/mab.html
(401) 782-9655

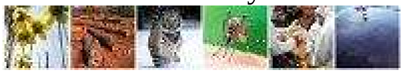
Theo Holtwijk, MA (Speaker)
Director of Long-Range Planning
Town of Falmouth, ME
tholtwijk@town.falmouth.me.us
http://www.town.falmouth.me.us/Pages/FalmouthME_Planning/index
(207) 781-5253

Pete Ingraham (webinar)
Applied GeoSolutions, LLC
Newmarket, NH
ping@agsemail.com
www.appliedgeosolutions.com/index.shtml
(603) 659-2392

Laura Jackson, PhD (Speaker)
Research Biologist
National Health and Environmental Effects Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
jackson.laura@epa.gov
(919) 541-3088

Ginger Jordan-Hillier
Environmental Public Health Coordinator
Maine Department of Environmental Protection
ginger.jordan-hillier@maine.gov
http://www.maine.gov/dep/
(207) 287-7863

Michael Kenyon
Director
New England Regional Laboratory
U.S. Environmental Protection Agency
kenyon.michael@epa.gov
www.epa.gov/ne/lab
617-918-8317



Katrina Kipp (Facilitator)
Manager
Ecosystem Assessment Unit
New England Regional Laboratory
U.S. Environmental Protection Agency
kipp.katrina@epa.gov
www.epa.gov/ne/lab
617-918-8309

Kathy Kudish, DVM, MSPH
Epidemiologist and Deputy State Public Health Veterinarian
Immunization Program
Connecticut Department of Public Health
kathy.kudish@ct.gov
www.ct.gov/dph/immunization
(860) 509-808

Eleanor Lacombe (webinar)
Vector-Borne Disease Laboratory
Maine Medical Center Research Institute
lacome@mmc.org
http://www.mmcri.org/lyme/lymehome.html
(207) 662-7142

Denise Leonard
Environmental Scientist
U.S. Environmental Protection Agency – Region 1
leonard.denise@epa.gov
(617) 918-1719

Cathleen Lepore (webinar)
cathylepore@hotmail.com

Timothy J. Lepore, MD, FACS (Speaker)
Surgeon, Nantucket Cottage Hospital
tjalepore@hotmail.com
(508) 228-4846

Sarah Levinson (Workshop Organizer)
New England Regional Laboratory
U.S. Environmental Protection Agency
levinson.sarah@epa.gov
(617) 918-1390

Ernst Linder (webinar)
Dept of Mathematics and Statistics
University of New Hampshire
Durham, NH
elinder@unh.edu

Charles Lubelczyk
Clinical Research Associate
Vector-borne Disease Laboratory
Maine Medical Center Research Institute
lubelc@mmc.org
http://www.mmcri.org/lyme/lymehome.html
(207) 662-7142

Kevin Moran (webinar)
Residex Company
Brewster, MA
kmoran@residex.com
(508) 896-4746

Matt Nicholson, PhD (Speaker)
Mid-Atlantic Environmental Assessment and Innovation Division
Region 3
U.S. Environmental Protection Agency
nicholson.matt@epa.gov
http://www.greeninfrastructure.net/content/event/green-infrastructure-linking-people-nature-and-landscapes
(215) 814-5386

Rick Ostfeld, PhD (Speaker)
Senior Scientist
Cary Institute for Ecosystem Studies
ostfeldr@caryinstitute.org
http://ecostudies.org/people_sci_ostfeld.html
(845) 677-7600, ext 136

Mary Pierce
Epidemiology Associate
Vermont Epidemiology Field Unit
Vermont Department of Health
mpierce@vdh.state.vt.us
http://healthvermont.gov/
(802) 863-7240

Joseph F. Piesman, DSc (Speaker)
Chief, Tick-Borne Diseases Activity
Bacterial Diseases Branch
Div. of Vector-Borne Infectious Diseases
National Center for Zoonotic, Vector-Borne and Enteric Diseases
Centers for Disease Control and Prevention
jfp2@cdc.gov
http://www.cdc.gov/nczved/
(970) 221-6408

Montira Pongsiri, PhD, MPH (Workshop Organizer)
Environmental Health Scientist
Office of the Science Advisor
U.S. Environmental Protection Agency
pongsiri.montira@epa.gov
http://www.epa.gov/osa/index.htm
(202) 564-0978

Meghan Radtke, PhD, AAAS Fellow (Workshop Organizer)
Office of the Science Advisor
U.S. Environmental Protection Agency
radtke.meghan@epa.gov
http://www.epa.gov/osa/index.htm
(202) 564-5553

Erin Rainone
Outreach Coordinator and Graduate Student
Center for Vector-Borne Disease
University of Rhode Island
erainone@uri.edu
http://www.tickencounter.org/
(401) 874-9505

Peter Rand, MD (webinar)
Senior Investigator
Vector-Borne Disease Laboratory
Maine Medical Center Research Institute
randp@mmc.org
http://www.mmcri.org/lyme/lymehome.html
(207) 662-7141

Kyle Ravana
Graduate Student
Wildlife Ecology Department
University of Maine
kyleravana@yahoo.com
(207) 478-0306

Alison Robbins, DVM, MS
Clinical Assistant Professor
Center for Conservation Medicine
Tufts Cummings School of Veterinary Medicine
alison.robbins@tufts.edu
http://www.tufts.edu/vet/ccm/
(617) 633-9082

Amy Robbins, MPH
Epidemiologist/Data Manager
Infectious Disease Epidemiology Program
Maine Center for Disease Control and Prevention
amy.robbins@maine.gov
http://www.maine.gov/DHHS/boh/
(207) 287-3332

Joe Roman, PhD
Editor, *Solutions* Magazine
Fellow, Gund Institute for Ecological Economics
University of Vermont
jroman@uvm.edu
http://www.uvm.edu/giee/
(802) 656-0517

Kirk Shively (webinar)
Wildlife Disease Biologist
USDA - Animal and Plant Health Inspection Service, Wildlife Services
kirk.j.shively@aphis.usda.gov
http://www.aphis.usda.gov/
(207) 622-8263

Paul Shoemaker, MPH
Associate Director
Environmental Health Office
Boston Public Health Commission
PShoemaker@bphc.org
http://www.bphc.org/Pages/Home.aspx
(617) 534-5966

Dave Simser
County Entomologist
Barnstable County Department of Health and Environment
simserdh@aol.com
http://www.barnstablecountyhealth.org/
(508) 776-3742

Betsy Smith, PhD (Speaker)
ReVA (Regional Vulnerability Assessment)
Program Director
Environmental Sciences Division
National Exposure Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
smith.betsy@epa.gov
www.epa.gov/reva
(919) 541-0620

Robert P. Smith, Jr., MD, MPH (Speaker)
Principal Investigator
Vector-Borne Disease Laboratory
Maine Medical Center Research Institute
smithr@mmc.org
http://www.mmcri.org/lyme/lymehome.html

Hilary Snook (Workshop Organizer)
Biologist
Ecosystem Assessment Unit
New England Regional Laboratory
U.S. Environmental Protection Agency
snook.hilary@epa.gov
www.epa.gov/ne/lab
(617) 918-8670

Laura Solem (webinar)
Minnesota Pollution Control Agency
laura.solem@state.mn.us
(218) 302-6628

Kirby C Stafford III, PhD (Speaker)
Vice Director, Chief Scientist, State Entomologist
Department of Entomology
Connecticut Agricultural Experiment Station
kirby.stafford@po.state.ct.us
http://www.ct.gov/CAES/
(203) 974-8485

Bret Stearns (Speaker)
Director
Natural Resources Department
Wampanoag Tribe of Gay Head (Aquinnah)
bstearns@wampanoagtribe.net
www.wampanoagtribe.net/Pages/index
(508) 645-9265

Ellen Stromdahl (webinar)
Entomologist
Tick-Borne Disease Laboratory
Entomological Science, Program
U.S. Army Center for Health Promotion & Preventive Medicine
ellen.stromdahl@us.army.mil
http://chppm-www.apgea.army.mil/
(410) 436-3613

Ellie Tonkin (Facilitator)
New England Regional Laboratory
U.S. Environmental Protection Agency
tonkin.elissa@epa.gov
www.epa.gov/ne
617-918-1726

Nathan Torbick (webinar)
Applied GeoSolutions, LLC
Newmarket, NH
torbick@agsemail.com
www.appliedgeosolutions.com/index.shtml

Kim Tsao
Doctoral Candidate, Epidemiology and Public Health
Division of Epidemiology of Microbial Diseases
Yale School of Public Health,
kim.tsao@yale.edu
http://publichealth.yale.edu/emd/index.html

Kyle Van Why (webinar)
USDA - Animal and Plant Health Inspection Service, Wildlife Services
kyle.r.vanwhy@aphis.usda.gov
http://www.aphis.usda.gov/
(717) 236-9451

Alan Vanarsdale
Environmental Scientist
Ecosystem Assessment Unit
Vanarsdale.alan@epa.gov
www.epa.gov/ne/lab
(617) 918-8610

Scott Weiant (webinar)
PA Department of Conservation & Natural Resources
sweiant@state.pa.us

Jeri Weiss (Facilitator)
New England Regional Laboratory
U.S. Environmental Protection Agency
weiss.jeri@epa.gov

Brian Zeichner (webinar)
brian.zeichner@us.army.mil