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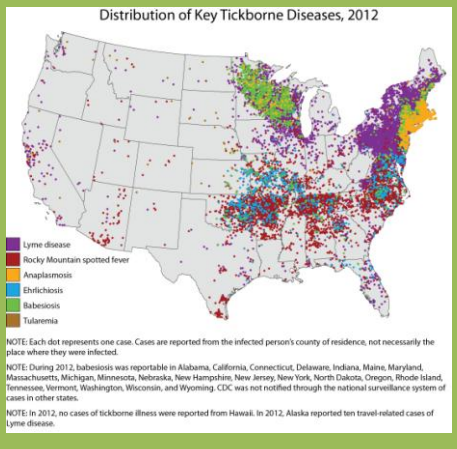
2014

Federal Initiative: Tick-Borne Disease Integrated Pest Management White Paper







CO-Editors

Charles Ben Beard, Ph.D.
And
Daniel Strickman, Ph.D.

Federal Agencies Providing Final Approvals:

Centers for Disease Control and Prevention (CDC)
US Environmental Protection Agency (USEPA)
US Department of Agriculture (USDA)
National Institutes of Health (NIH)
US Department of Defense (DOD)
US Department of Interior (DOI-USGS)
National Science Foundation (NSF)

Major Contributors as
Federal Tick-Borne Disease Integrated Pest Management Workgroup Members :

Charles Ben Beard, Ph.D., (CDC), Herbert Bolton, Ph.D., (USDA NIFA), Candace Brassard, M.S. (USEPA), Joseph Breen, Ph.D. (NIH), John Carroll, Ph.D. (USDA ARS), Adriana Costero, Ph.D. (NIH), Carol DiSalvo, M.S. (NPS), Frank Ellis, M.S. (USEPA), Howard Ginsberg, Ph.D. (USGS), Greg Hellyer, M.A. (USEPA), Susan Jennings, M.A. (USEPA), Robert Koethe, Ph.D. (USEPA), Angela James, Ph.D. (USDA APHIS), Matthew Messenger, Ph.D. (USDAAPHIS), Joseph Piesman, Ph.D. (CDC), Samuel Scheiner, Ph.D.(NSF), Daniel Strickman, Ph.D. (USDA ARS), and Ellen Stromdahl, M.S. (USDOD)

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LYME DISEASE AND OTHER TICK-BORNE DISEASES OF HUMANS IN THE UNITED STATES

I. INTRODUCTION

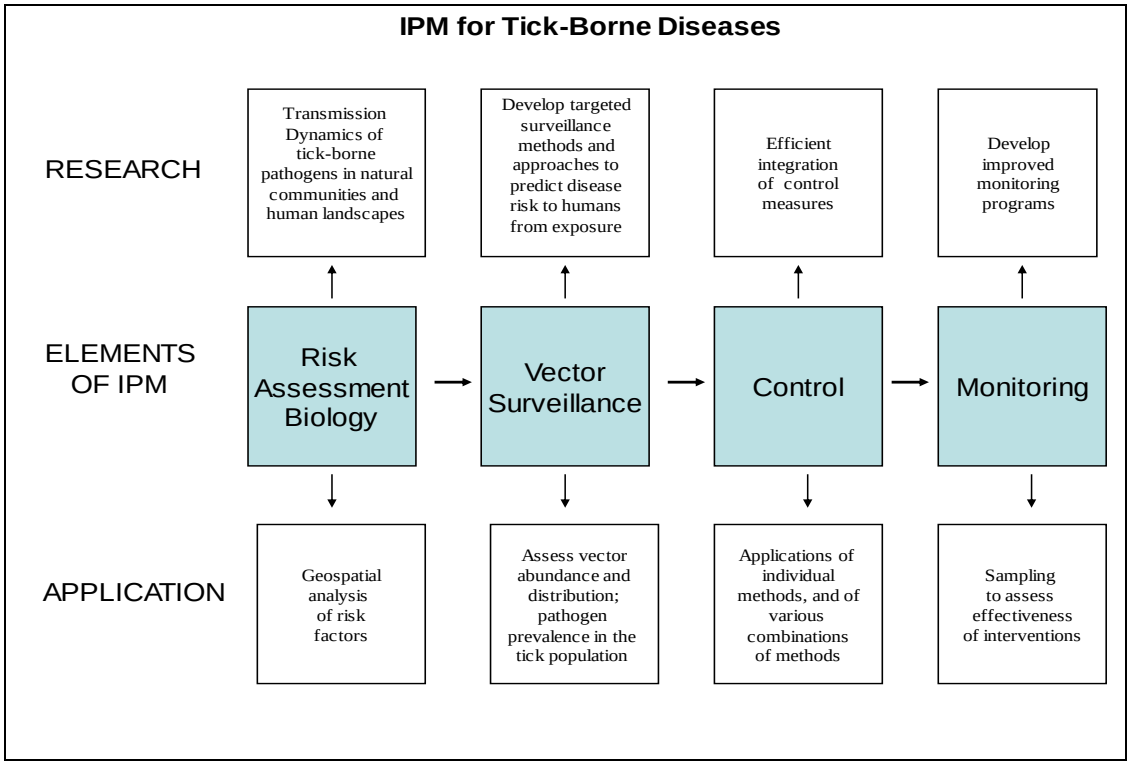
The numbers of human cases of Lyme disease and other tick-borne diseases (TBDs) reported each year to CDC have been increasing steadily in the United States (US), currently totaling tens of thousands of diagnosed human cases annually (Table 1). The reasons behind this increase are complex and involve multiple factors including: (1) ecological changes, possibly including climate change, and shifts in land use patterns, (2) increasing deer and wildlife populations and closer associations between humans and wildlife, (3) human behavioral changes that have led to greater exposure risks, and (4) improvements in disease diagnosis, surveillance, and reporting practices.

Integrated Pest Management (IPM) is a scientific strategy that uses pest surveillance and multiple control methods synergistically to reduce populations of target arthropod pests. The goal of IPM for prevention of TBDs is to reduce human illness and associated economic costs while minimizing potential environmental impacts. Discussions and consensus building between stake holders, site users, and technical experts can help form an effective management strategy. Educational components help people reduce their risk of tick encounters, via improved awareness of landscape design and personal protection. Adaptive Management can be a helpful concept by promoting the periodic evaluation of protocols and results, incorporating newly learned information to improve the management strategy.

Multiple US federal agencies currently share responsibility in addressing various aspects of TBD problems in the US. Through the coordination of efforts across these agencies, the US government has the opportunity to improve efficacy of control and reduce the risk from TBD. The Tick-borne Diseases Integrated Pest Management Workgroup (TBD IPM WG) was created for the purpose of enhancing communication and collaboration among US federal agencies involved in tick management as it relates to human health, companion animals, and wildlife that may serve as potential zoometric reservoirs of human disease.

The following figure identifies how Integrated Pest Management may reduce exposure to ticks that carry pathogens that cause tick-borne disease, e.g., Lyme disease, babesiosis, ehrlichiosis and anaplasmosis. Adaptive Management can help keep the program focused and effective by responding to measured effects in real time.

Figure 1.Interrelationship of IPM for Tick-Borne Diseases



The Tick-Borne Disease IPM Workgroup will:

- Collect, share, organize, and integrate information on best practices, including communications tools and resources, related to IPM of ticks and TBDs.
- Identify and prioritize research gaps and needs.
- Share agency-specific strategic plans relating to the control of ticks and the pathogens they may transmit.
- Develop white papers and a strategy for tick IPM and prevention of TBD and consensus documents that can be shared across US federal agencies for the purposes of improving and coordinating IPM programs and activities.

II. RECOMMENDATIONS

A. SET COMMON GOALS

The TBD IPM WG proposes the following recommendations for federal activities that would contribute toward a reduction of the disease burden from pathogens transmitted by ticks. Coordination and development of a formal inter-agency workgroup is useful to maximize the efficient use of resources and to increase the knowledge base for all federal partners. This function also promotes consistent policies between all agencies, where appropriate. The following are common goals:

1) Establish formal relationships to coordinate basic and applied research efforts on human and environmental health (CDC, DOD, EPA, NSF) with research on health of wildlife (DOI USGS, APHIS) and domesticated food animals (ARS).

2) Facilitate opportunities to coordinate basic research (NIH, NIFA) with applied research and field trials on federal lands (DOD, CDC, NPS, ARS, APHIS, and NIFA).

3) Coordinate multi-agency research to optimize decision-making for management of tick-borne diseases.

4) Foster inter-agency collection and management of geospatial information about vectors and vector-borne diseases, and of parameters indirectly related to human risk. Facilitate archiving and access to geospatial information (ARS, APHIS, NIFA, DOI, USGS, DOD Walter Reed Army Institute of Research, Smithsonian Institution, and EPA).

B. ESTABLISH COLLABORATIVE RESEARCH DIRECTIONS

Federal support is dedicated towards studying tick vectors and the pathogens they transmit, conducting tick surveillance, identifying and confirming human health exposure, and developing tools for preventing or reducing exposure to ticks that transmit disease pathogens. The following are common priorities:

1) To promote additional research on relationships between human behavior and TBD transmission (CDC and NIH).

2) To validate efficacy of various IPM methods in reducing human illness associated with TBDs (CDC and NIH).

3) To promote development of scale-sensitive, risk-based modeling tools for IPM (CDC, ARS, APHIS, NIFA, and EPA).

C. Continue Community Outreach, Education, and Collaboration

Federal partners provide educational material on ticks and associated pathogens which may be transmitted and cause disease. The information provided varies depending on the mission of each agency. Federal agencies may also leverage their resources to encourage prevention activities in collaboration with local organizations and municipalities. The following are common communication outreach, education, and prevention goals:

1) To provide evidence-based toolkits and other resources on prevention best practices to state and local public health partners.

2) To educate the public living in areas of risk on the efforts they can take to reduce risk of exposure to TBDs.

3) To develop and share information regarding landscape designs to reduce human / tick interaction.

4) To encourage efforts for targeted management of ticks in areas of highest TBD incidence.

5) To prepare joint and individual agency statements on TBDs to be incorporated into strategic and action plans.

6) To identify TBD experts in each federal agency for public outreach.

III. Integrated Pest Management

The original concept of Integrated Pest Management described in Robert Metcalf and William Luckmann's seminal book (*Introduction to Insect Pest Management,* 1975, John Wiley & Sons) reached back to earlier work that was a response to the collapse of pest control based on what is now understood to be an overuse of organochlorine insecticides. Citing P.W. Geier (1966. Management of insect pests. Ann. Rev. Entomol. 11: 471-490), they defined pest management with three elements: "(1) determining how the life system of a pest needs to be modified to reduce its numbers to tolerable levels, that is, *below the economic threshold;* (2) applying biological knowledge and current technology to achieve the desired modification, that is, *applied ecology;* and (3) devising procedures for pest control suited to current technology and compatible with economic and environmental quality aspects, that is, *economic and social acceptance.*" Those three elements still emphasize purposes that probably all modern definers of IPM would agree upon, namely that actions should be taken in response to actual need, that control techniques should be used intelligently and taking advantage of the pest's biological characteristics, and that an IPM program must do no harm to the environment while still being practical economically. They considered the final development of sustainable, rational, efficient pest control as the "Integrated Control Phase," the system we would ideally develop for all pests.

A. Federal Implementation of IPM

The Food Quality Protection Act of 1996 defines Integrated Pest Management (IPM) as, "....a sustainable approach to managing pests by combining biological, cultural, physical, and chemical tools in a way that minimizes economic, health, and environmental risks."

Similar to Metcalf and Luckmann's definition, this statement is more about the goals and purposes than how to achieve them. EPA's Integrated Pest Management Fact Sheet (EPA 731-F-10-005) goes on to list the following actions to take: 1) set action thresholds, 2) monitor and identify pests, 3) prevention, and 4) control.

The Action Plan for USDA ARS' National Program for Veterinary, Medical, and Urban Entomology provides an alternative functional definition of IPM based on sequential activities and motivated by a need to categorize the research required to achieve IPM.

Implementation of an Effective Tick IPM Strategy in a School

At a Maryland school, black-legged ticks, *Ixodes scapularis* and lone star ticks, *Amblyomma americanum,* were being found on students after their participation in outdoor school activities.

After discussion with the Parent-Teacher Association and school administrators, and in collaboration with local, state, and federal government specialists, IPM tactics were implemented to reduce student and staff exposure to ticks. These tactics included placement of a "4-poster" acaricide device, improved landscape management, playground area restrictions, and increased personal protection measures.

USDA ARS provided essential tick monitoring that demonstrated the success of the school's tick IPM program.

B. National Road Map for IPM

Integrated Pest Management is a long-standing, science-based, decision-making process that identifies and reduces risks from pests and pest management related strategies. It coordinates the use of pest biology, environmental information, and available technology to prevent unacceptable levels of pest damage by the most economical means, while posing the least possible risk to people, property, resources, and the environment. IPM provides an effective strategy for managing pests in all arenas from developed agricultural, residential, and public areas to wild lands. IPM serves as an umbrella to provide an effective, all encompassing, low-risk approach to protect resources and people from pests. A multi-agency endorsed road map can be found at www.ars.usda.gov/Research/docs.htm?docid=12430.

C. Five Elements of IPM

IPM can be divided into five elements: 1) risk assessment/biology, 2) pest surveillance, 3) control, 4) monitoring/sustainability, and 5) adaptive management. The following is a description of each element:

1) Risk assessment/biology is the first necessary step for any IPM program. Background information on the identification (systematics and taxonomy), distribution (spatial and temporal), behavior (particularly potential for causing damage), and developmental biology of the pest defines the problem and suggests strategies for its control. Research on almost any aspect of the pest's biology can contribute toward the practical goals of risk assessment. In a sense, biological studies contribute toward risk assessment by improving our ability to "know thy enemy." Further, when the damage is caused by a pathogen transmitted by the pest (i.e. vector), an understanding of the pathogenesis and epidemiology is also important. This knowledge of the relationship between the vector and the pathogen can lead to a much better understanding of the problem. Particularly useful tools for risk assessment include geographic information systems and spatial analysis, especially when they are applied at a sufficiently local level to direct the next steps in IPM.

2) Pest surveillance is the measurement of factors that inform the IPM program about where to concentrate control measures. Examples include detection and enumeration of the pest species, its damage, and human illness. Surveillance activities can also include assessment of specific risk factors that contribute to exposure to ticks and the pathogens they transmit. It can also include behavior studies, as well as measurement of correlates such as soil moisture or canopy density that can be related to pest population size. Trap development and interpretation of trapping results are important surveillance-related activities.

3) Control in the case of vector-borne pathogens includes self-protection measures, vaccination, treatment of infections, and entomological measures to reduce vector populations (e.g., biological control, landscape management, and chemical control). In practice, each method is applied individually and locally, so that projection of research results from the laboratory to the human community (where there are combinations of interventions) is especially challenging. Carefully determining appropriate measures needed to reduce risk can make a big difference in effectiveness, efficiency, and safety of an IPM program. Each control program must balance risk and benefit, but the admonition to "do no harm" to the environment, applicator, and consumer should be at the foundation of all research on this aspect of IPM.

4) Monitoring a pest to ensure continuous, successful IPM has proven very difficult for the field of entomology as it relates to human disease. Public health organizations may lose interest in the problem during periods of lower disease incidence. Monitoring for sustainability requires systems that can accurately detect the reappearance of the pest, its damage, or disease caused by a transmitted pathogen. In general, entomological research in the area of public health has concentrated its efforts more on surveillance for control rather than monitoring for sustainability, with the result that many successful IPM programs have eventually failed as operational resources were diverted to other problems. In many cases, the technical tools of vector surveillance will be the same as those for monitoring, but the deployment of those tools will be different.

5) The Adaptive Management concept is used to evaluate, analyze the actions, documentation, and results implemented in the first three elements and modify the protocols to improve the process for further reducing risk.

However IPM is defined, it is probably most useful as a concept when it is separated from biases associated with chemical use and natural control methods. Input from stakeholders influences the types of measures used locally to manage vector-borne diseases. Considerations such as chemical (biopesticide or conventional) use versus use of self-protection or natural[1] approaches (or combinations of these) are considered and are included in the decision-making process for area-wide management. Construction of a good IPM plan and implementation of a program is not usually easy and may require input of many kinds of skills. Constant adjustment often requires inputs from professionals and thoughtful self-examination of the progress of a program.

Black legged tick, *Ixodes scapularis*, adult-female-dorsal
Photo: Graham Snodgrass, US Army Public Health Command.

IV. MILESTONES

A. WHITE PAPER ON NEEDS AND STRATEGIC PRIORITIES

B. FEDERAL CONFERENCE ON WHITE PAPER AND STRATEGIC PLANNING

C. SYSTEMATIC COLLECTION OF PUBLIC INFORMATION ON LOCAL NEEDS

D. STAKEHOLDER OUTREACH THROUGH THE FEDERAL WORKGROUP

E. INFORMATION CLEARINGHOUSE ON TICK IPM

[1] Natural is a subjective term, often interpreted differently by the individual user. Most people seem to feel that a natural product is derived from materials that have been little altered from their original state, such as plant extracts, pulverized minerals, etc. The term might also be applied to changes in the environment that discourage ticks, for example, by cutting grass below the level that allows their development. Finally, some seem to view anything natural as inherently safer, presumably because organisms have always been exposed to the natural substance or situation.

V. BACKGROUND

The agencies participating in formulating the recommendations are responsible for implementing broad missions within their respective agencies for IPM and TBD. Collaborating federal partners identify existing knowledge, successful IPM practices, and research needs. These tools may support future decisions among the federal sector for TBD IPM. The following is an overview of TBDs and IPM in the United States:

A. INCIDENCE AND DISTRIBUTION

Tick-borne diseases (TBDs) are common throughout much of the United States today. With approximately 30,000 cases per year, Lyme disease is the 6th most common disease reported to the Centers for Disease Control and Prevention (CDC) and the most common vector borne disease (Table 2). Other important TBDs in the US include anaplasmosis, babesiosis, ehrlichiosis, Rocky Mountain spotted fever, tick-borne relapsing fever, Colorado tick fever, Powassan encephalitis (including deer tick fever), and tularemia (Table 3). The distributions for the most common of these are shown in Figure 1.

B. ECOLOGY AND EPIDEMIOLOGY

Tick-borne diseases typically are maintained in zoometric cycles in which humans are dead-end hosts that are not involved in maintaining the disease in nature. In the case of Lyme borreliosis, small mammals and sometimes birds serve as reservoirs for the spirochete. The agent is transmitted between animals and to humans by the blacklegged tick, *Ixodes scapularis,* in the eastern and upper Midwest regions of the US and by the western blacklegged tick, *I. pacificus,* in the coastal western US. Deer are refractory to *Borrelia burgdorferi* infection and therefore not reservoirs for the pathogen. They are an important host for adult *I. scapularis* ticks and serve ecological roles for establishment and maintenance of *I. scapularis* populations.

C. CURRENT TRENDS

The numbers of TBDs occurring in the US have generally been increasing over the last decade (Table 1). The explanation for this increase is thought to be associated with multiple factors including reforestation and changing land use patterns, overabundant deer populations, and expansion of suburbia into wooded areas, resulting in larger populations of ticks and greater risks for human exposure. Improvements in diagnosis and in surveillance and reporting practices have also contributed to the increasing numbers of cases of TBDs. The change in the diagnosis and reported number of Lyme disease cases over the last 15 years is shown in Figure 2. Significant areas of expansion can be seen in the upper Midwest (Minnesota and Wisconsin) and in the Northeast, where the distribution has increased westward across Massachusetts and Pennsylvania and northward up the Hudson and Connecticut River valleys and into Vermont, New Hampshire and Maine. The generally northward expansion of Lyme disease has generated much interest in the possibility of climate change as a driving force. It is also important to note that over the same 15-

year period of time, southward expansion has also occurred through Delaware, Maryland, Virginia, and into coastal North Carolina, suggesting that other biological drivers are also involved in Lyme disease expansion. Several tick species, in addition to *I. scapularis* , are also expanding their ranges (e.g., *Amblyomma americanum).*

D. TICK-BORNE DISEASE PREVENTION

TBD prevention depends primarily on efforts to reduce exposure of humans to potentially infected ticks. This can be accomplished through educating at-risk populations to use protective measures such as avoiding tick habitat, wearing protective clothing, using insect repellents and permethrin treated clothing, checking for ticks daily, and bathing promptly following potential exposure. Other methods of reducing exposure to ticks include landscape management, the use of area acaricides (including bait boxes and deer-4-poster devices), and other strategies to reduce the number of infected ticks on hosts and in areas where they may contact humans.

Table 1. Tick-borne diseases reported to the CDC, United Stated, and 2002-2011 [Source: CDC]

Disease	Year									
	2002	2003	2004	2005	2006	2007	2008	2009§	2010	2011
Lyme	23,763	21,273	19,859	21,304	19,931	27,444	35,198	38,468	30,158	33,097
RMSF	1,104	1,091	1,738	2,029	2,288	2,221	2,563	1,815	1,985	2,802
Eh/An (total)*	750	727	934	1,404	1,455	1,999	2,107	2,267	2,615	3,562
Babesiosis‡										1,128

§Reporting criteria revised in 2009

*Includes human granulocytic anaplasmosis and human monocytic ehrlichiosis

‡Babesiosis became nationally notifiable in 2010

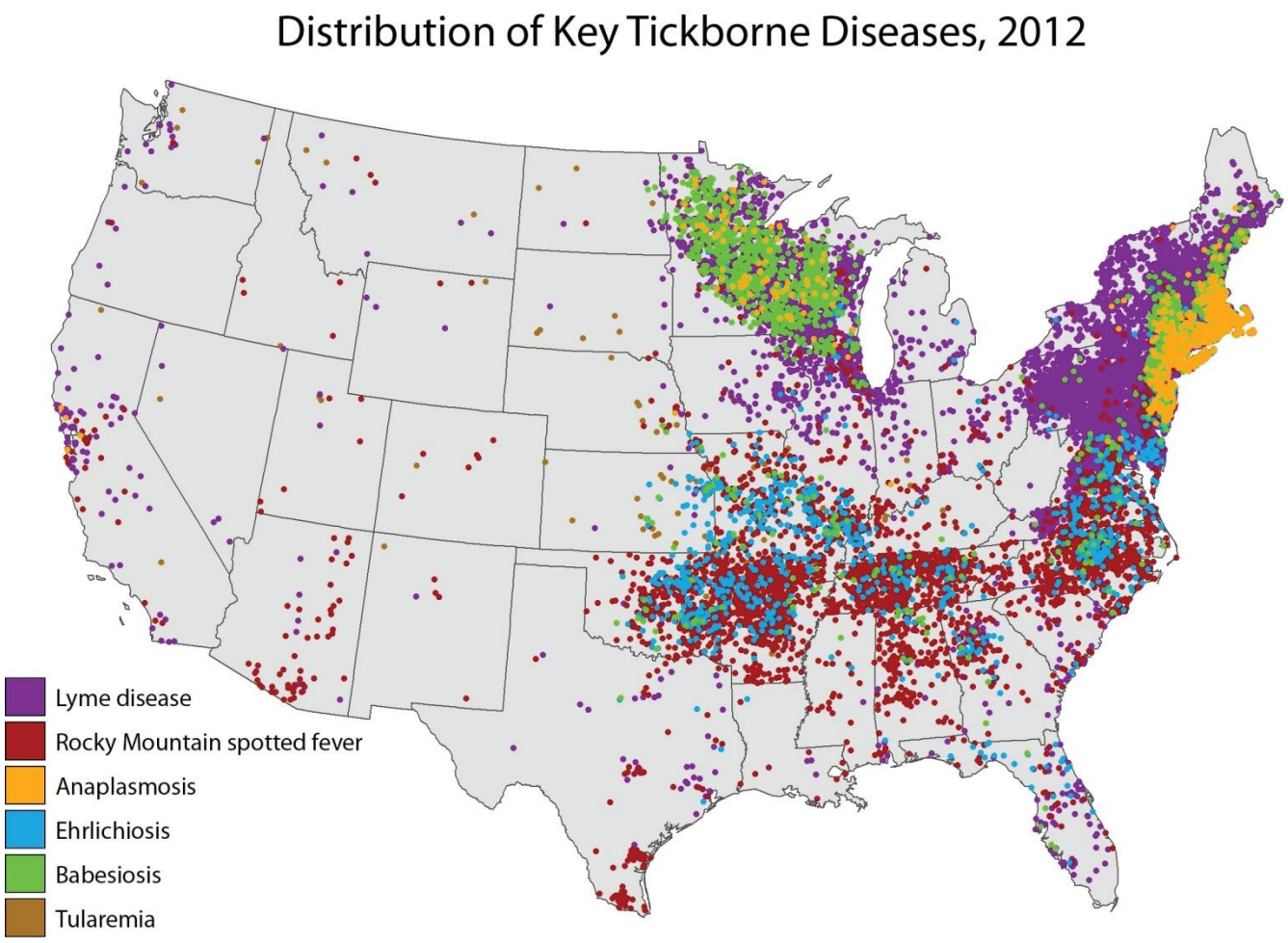
Table 2. Top notifiable diseases to the CDC, United States, 2011 [Source: CDC]

Disease/agent	Case numbers
1. Chlamydia	1,412,791
2. Gonorrhea	321,849
3. Salmonellosis	51,887
4. Syphilis	46,042
5. HIV/AIDS (new cases)	35,266
6. Lyme disease	**33,097**
7. Coccidioidomycosis	22,634
8. Pertussis	18,719
9. *Streptococcus pneumoniae*	17,138
10. Giardiasis	16,747

Table 3. Tick-borne diseases reported to the CDC, United States, 2011 [Source: CDC]

Disease/agent	Reported cases
Lyme disease	33,097
Spotted Fever Rickettsiosis	2,802
Anaplasma phagocytophilum	2,575
Babesia	1,128
Ehrlichia chaffeensis	850
Tularemia	166
Anaplasma/Ehrlichia – undetermined/other	161
Powassan virus	16

Figure 2. Distribution of tick-borne diseases in the United State, 2012 [Source: CDC]

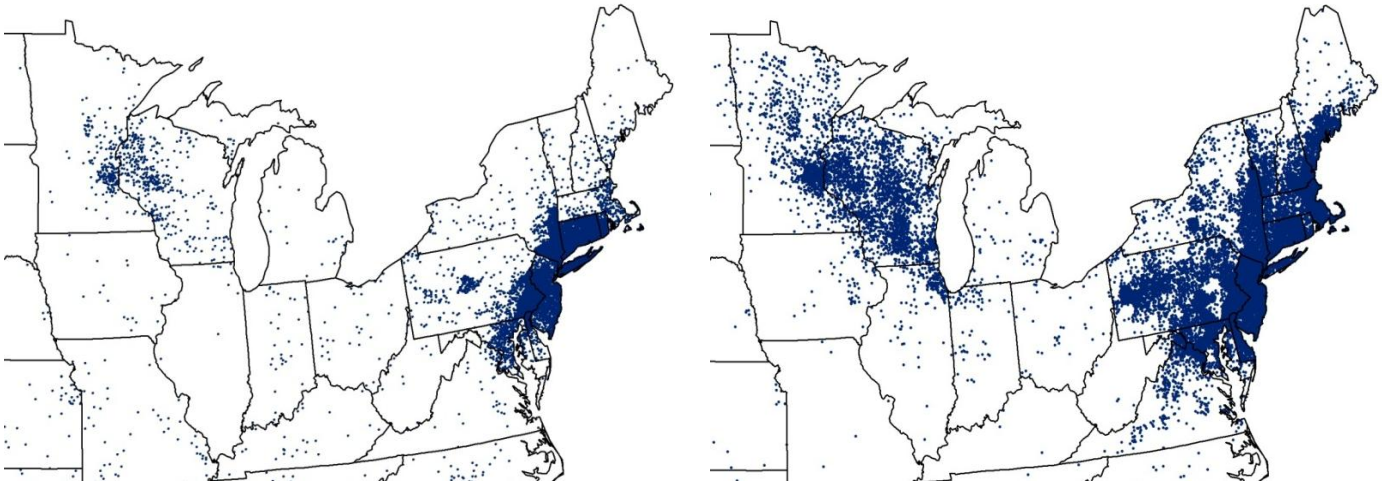


NOTE: Each dot represents one case. Cases are reported from the infected person's county of residence, not necessarily the place where they were infected.

NOTE: During 2012, babesiosis was reportable in Alabama, California, Connecticut, Delaware, Indiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Nebraska, New Hampshire, New Jersey, New York, North Dakota, Oregon, Rhode Island, Tennessee, Vermont, Washington, Wisconsin, and Wyoming. CDC was not notified through the national surveillance system of cases in other states.

NOTE: In 2012, no cases of tickborne illness were reported from Hawaii. In 2012, Alaska reported ten travel-related cases of Lyme disease.

Figure 3. Lyme disease case distribution, United States: 16-year trend [Source: CDC]



1996 2011

Lone Star Tick, Female, *Amblyomma americanum*- adult
Photo: Graham Snodgrass, US Army Public Health Command

VI. AGENCY MISSIONS

Each agency has its own mission that evolves over time as needs change and priorities shift. For some agencies, there may be statutes or congressional appropriation language that establishes specific responsibilities. In other instances, the agency may examine the problems associated with TBDs and with the help of customers and stakeholders, evaluate whether there is a role to play and how to approach the specific problems identified that fall within that agency's mission. Communication between agencies can reduce duplication of effort and allow each agency to concentrate on its own strengths while contributing

solutions to problem as a whole. Often, agencies are able to collaborate directly either by combining efforts or sharing resources. The rest of this section describes the mission of the federal agencies represented in this white paper, as it relates specifically to the topic of IPM for TBDs.

A. Centers for Disease Control and Prevention (CDC)

The Centers for Disease Control and Prevention (CDC) serves as the national focus for developing and applying disease prevention and control, environmental health, and health promotion and health education activities designed to improve the health of the people of the United States. CDC is responsible for controlling the introduction and spread of infectious diseases, and provides consultation and assistance to other nations and international agencies to assist in improving their disease prevention and control, environmental health, and health promotion activities.

1) Programs and activities at CDC that are directed toward IPM of TBDs are housed in two centers and one institute within the agency – the *National Center for Emerging and Zoonotic Infectious Diseases*, the *National Center for Environmental Health*, and the *National Institute for Occupational Safety and Health*. Some of the specific activities relevant to Lyme and other TBDs include the following: Conducting multidisciplinary public health-oriented research aimed at developing effective prevention and control measures for TBDs.

2) Coordinating nation-wide TBD human surveillance with state and local health departments.

3) Serving as the national diagnostic and reference laboratory for tick-borne diseases in humans.

4) Providing science-based guidance, recommendations, and technical assistance for prevention and control of TBDs.

5) Training students, fellows, and public health practitioners for the purpose of diagnosing, preventing, and investigating TBDs.

6) Collaborating with universities, industry, and public health partners in promoting sound disease prevention policies and practices

7) Building capacity in local, state, and tribal environmental health programs by providing IPM training for workforce development and by promoting vector control programs.

B. US Department of Agriculture (USDA)

1) Animal and Plant Health Inspection Service (APHIS)

The mission of APHIS is "To protect the health and value of American agriculture and natural resources." APHIS is engaged in conducting surveillance, risk assessments, and animal treatments for ticks on imported and domestic livestock and wildlife. These exotic and domestic tick species are considered potential vectors of tick-borne diseases of humans, such as Lyme disease, babesiosis, and anaplasmosis.

2) AGRICULTURAL RESEARCH SERVICE (ARS)

As USDA's chief scientific, in-house research agency, ARS is responsible for finding solutions to agricultural problems that affect Americans every day, from field to table. ARS conducts research to develop and transfer solutions to agricultural problems of high national priority and provide information access and dissemination. The mission areas of ARS are Nutrition, Food Safety and Quality; Natural Resources and Sustainable Agricultural Systems; Crop Production and Protection; and Animal Production and Protection.

Protection of humans from ticks has been a logical by-product of veterinary efforts, especially when the tick species attack both humans and animals. Major research efforts by the ARS in support of the Cattle Fever Tick Eradication Program have worked on solutions to the problem of reducing tick populations associated with wild deer. Those efforts have had beneficial results not only for control of the cattle fever tick on deer, but also control of Lyme disease vectors on deer. The ARS veterinary entomology program has accepted the challenge of determining the effects of climate change on risks to livestock from ticks, which will have implications for prediction of risk to human health. The research program also develops new products with traditional uses, such as acaricides and repellents. Many of those products will be equally effective against ticks that bite either livestock or humans.

One laboratory within ARS includes the mission of developing better methods to control Lyme disease vectors. That laboratory is well positioned to translate the larger veterinary mission into new solutions that prevent tick borne diseases of humans. Efforts to date have included evaluation of area wide control programs and development of new repellents.

3) NATIONAL INSTITUTE OF FOOD AND AGRICULTURE (NIFA)

NIFA is USDA's chief scientific extramural agency for research, education, and extension. NIFA is one of four USDA agencies that make up its Research, Education, and Economics (REE) mission area. The other three agencies are:

- Agricultural Research Service (ARS)
- Economics Research Service (ERS)
- National Agricultural Statistics Service (NASS)

The USDA-REE agencies provide federal leadership in creating and disseminating knowledge spanning the biological, physical, and social sciences related to agricultural research, economic analysis, statistics, extension, and higher education.

NIFA's unique mission is to advance knowledge for agriculture, the environment, human health and well-being, and communities by supporting research, education, and extension programs in the Land-Grant University System and other partner organizations. Some of NIFA's programs and funding opportunities are specific to the Land-Grant University System while others are open to participation by other organizations. NIFA helps fund research, education, and extension at the state and local level and provides program leadership in these areas. NIFA also provides partial funding and leadership for the national extension program, which has resources on ticks.

Tick-borne disease research, education, and extension do not comprise a separate program area within NIFA's funding portfolio. However, NIFA has funded specific tick-borne disease projects through various funding programs. NIFA collaborates with NSF on the Ecology and Evolution of Infectious Diseases (EEID) program. NIFA funds the IR-4 Project.

4) IR-4 Project Funded by USDA

The mission of the IR-4 Project, a cooperative venture of the USDA and the state land grant universities, is to facilitate registration of sustainable pest management technology for specialty crops and minor uses, including public health. The IR-4 Project Public Health Pesticides Program maintains an inventory of public health pesticides, with particular emphases on efficacy vs. various pests (including ticks), regulatory status of materials, physic-chemical attributes. IR-4 seeks to identify underutilized materials with potential utility vs. ticks and other vectors, to provide regulatory support for materials moving towards practical use, to help provide the data needed to support and expand existing registrations, and to help improve the process of bringing new vector control tools into the toolbox.

C. US Department of Defense (DOD)

The mission of the Department of Defense is to deter war and protect the security of the country. In order to do this, they must maintain the health and safety of military members, their families, and DOD civilian employees. Disease and Non-Battle Injuries (DNBI) account for more casualties than combat. Ticks are one of the major vectors of disease that threatens military personnel, families, and civilian employees on US military installations. DOD is currently involved in tick and tick-borne disease surveillance, tick-borne disease diagnosis, tick taxonomy and imaging, and work on tick repellents.

The Armed Forces Pest Management Board (AFPMB) is a tri-service coordinating body that makes recommendations for IPM, provides expert advice on use and availability of entomological products including acaricides, and coordinates certification of pesticide applicators. The AFPMB has no direct command and control responsibilities. Each service has its own system for advising and administering IPM: the Army through Public Health Command (USAPHC) (technical direction) and the Army Medical Department Center and School (training and product deployment); the Navy through the Navy and Marine Corps Public Health Center (NMCPHC); and the Air Force through the School of Aerospace Medicine.

Entomological interventions are accomplished for the most part by civilian employees and contractors on domestic and foreign bases, with various military units involved during combat and in other situations. The Army's assets are concentrated in a series of Preventive Medicine Units equipped and trained for IPM, the Navy deploys specialized teams tailored to a particular situation, and the Air Force includes pesticide applicators as a military specialty who performs their duties as part of public works. All three branches have uniformed professional entomologists who perform various duties of command, oversight, expert advice, and administration.

The military has a strong research program in entomology, the emphasis of which is on malaria and dengue. TBD research has been pursued through development of IPM, diagnostics,

personal protection, and surveillance. In partnership with USDA, the military developed what has been the most effective tool against ticks for military personnel—the permethrin treated uniform. Entomological research in the military is principally funded through the US Army Medical Research and Materiel Command's Military Infectious Diseases Research Program (MIDRP). MIDRP channels funding for medical entomology research to the Walter Reed Army Institute of Research (and its overseas laboratories in Thailand, Georgia, and Kenya), the Navy Medical Research Center (and its overseas laboratories in Hawaii, Peru, and Egypt), and the US Army Medical Research Institute for Infectious Diseases. In addition, the Navy Entomology Center of Excellence (Jacksonville Naval Air Station) under NMCPHC, the USAPHC (including locations in Japan and Germany), and the 5th Preventive Medicine Unit (Korea) perform significant applied research.

D. US Environmental Protection Agency

EPA supports many aspects of zoometric disease science and policy through core programs and through special research. Agency programs that share responsibility for IPM and TBD prevention are as follow:

1) Office of Pesticide Programs (OPP)

EPA's Office of Pesticide Programs registers or licenses pesticides for use in the United States. In addition, states register or license pesticide for use within individual states. EPA receives its authority and responsibility to register pesticides for specified uses under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). States are authorized to enforce pesticide use and certify and train applicators of restricted use products under FIFRA. State pesticide laws may be more restrictive than the federal requirements but states may not change product labels. Pesticides must be registered both by EPA and the state before sale and distribution.

Key EPA and state pesticide regulatory activities include:

- Evaluating potential new pesticides and uses
- Exploring new approaches to minor uses
- Providing for Special Local Needs (FIFRA Sect. 24C) and Emergency situations (FIFRA Sect. 18)
- Reviewing data on currently registered pesticides
- Registering pesticide producing establishments
- Enforcing pesticide labeling and use requirements

OPP also regulates pesticides imported for use in the United States and participates in a wide variety of international activities, such as regulatory agreements and coordination activities.

In general, states have primary authority for compliance monitoring and enforcing against use of pesticides in violation of the labeling requirements. EPA works cooperatively with tribal governments to enforce FIFRA, as it does with states and territories. EPA also

provides funding to tribes to assist in the development and implementation of pesticide programs under tribal law.

- Ticks, as vector pests, are considered public health pests of concern (EPA Pesticide Registration Notice 2002-1). OPP specifically supports the control of these public health pests by pesticide product registration of acaricides (e.g., repellents, treated clothing, outdoor area treatment)
- Coordinating with EPA's enforcement office, the EPA Regional Offices, and the states to ensure enforcement of pesticide regulations
- Financial support and technical expertise for pesticide applicator certification and training, as well as pesticide safety education

In addition to its regulatory role, EPA supports IPM and environmental stewardship efforts through grant programs, collaborations, and partnerships with states, tribes, universities, companies, nonprofit organizations, and community groups. Partnerhsips provide opportunities for EPA staff to access expertise and real world knowledge that can help address issues related to pest and pesticide risk and stewardship. Involvement in partnerships with EPA also gives pesticide-related professionals a unique opportunity to work with federal regulators and scientists in an environment of respect and collaboration.

OPP's PestWise umbrella represents a collaborative suite of programs that promote environmental innovation in pest management where we live, work, learn, play, and farm. This includes the Pesticide Environmental Stewardship Program, a partnership program that works with the nation's pesticide-user community to promote IPM practices. It also encompasses other IPM activities including those focused on schools, TBD prevention, multi-family housing, and agriculture. OPP, as a co-lead of the federal TBD IPM workgroup, contributes to the identification of research needs for TBD IPM and promotes the development of effective tools for measuring success of TBD IPM initiatives.

2) Office of Research and Development (ORD) and New England (Region 1)

The Office of Research and Development is the scientific research arm of EPA, whose leading-edge research helps provide the solid underpinning of science and technology for the Agency. Through the Office of the Science Advisor and in close collaboration with EPA-New England (Region 1) and collaborators, ORD has been developing a *Biodiversity, Landscape Change and Human Health Community of Practice* (CoP).

"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" (Wenger 2006; www.ewenger.com/theory/). The workshops and CoP support EPA's Biodiversity and Human Health Initiative:

> "*EPA recognizes the importance of healthy ecosystems for our health and well-being, and conserving biodiversity is a primary way to sustain healthy ecosystems and the services they provide to us. One ecosystem service EPA is trying to better characterize is disease regulation – that is, maintaining biodiversity may protect us against*

emerging diseases like Lyme disease and West Nile virus."
(www.epa.gov/ncer/biodiversity/).

E. US Department of the Interior (DOI)

The US Department of the Interior (DOI) protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future. The DOI's Mission Statement is to: Protect America's Great Outdoors and Power Our Future. Several DOI initiatives specifically address tick-borne disease and risk management. These include: 1. The DOI One Health Group, which utilizes a Department-wide interdisciplinary coordinated approach to promote the health of all species and the environment in the stewardship of our public lands, and promotes sound science with inter-agency collaboration to inform policy and management decisions for issues at the interface of wildlife, domestic animal, and human health; 2. The Department Manual 517- Integrated Pest Management which directs Bureaus to follow an IPM approach and, 3. the DOI Safety Management Information System (SMIS) Safety Net which tracks injuries and illnesses Department-wide and provides on-line, shared occupational health resources for all Interior bureaus and offices. A specific function for reporting cases of tick-borne disease has recently been incorporated to this system.

1) US Geological Survey (USGS)

The USGS is the research agency within the Department of the Interior (DOI). Tick-borne disease is not a separate mission area within USGS. Nevertheless, extensive research efforts related to wildlife health and to human health issues that are associated with zoometric diseases are included in the Ecosystems mission area. The National Wildlife Health Center maintains extensive research programs and provides technical consultations on wildlife diseases, including those caused by tick-borne pathogens. USGS scientists provide technical support to other DOI agencies, including the National Park Service and the Fish and Wildlife Service, on surveillance and management of tick-borne diseases on federal lands.

2) National Park Service (NPS)

The Mission of the NPS is to preserve unimpaired the natural and cultural resources of the United States for the American people and future generations. Several program areas coordinate to address aspects of tick-borne disease. The NPS Public Health Program promotes a safe and healthy National Park visitor experience while also preserving the environment and wildlife. The Integrated Pest Management Program develops IPM policy, provides technical IPM assistance and training, and tracks and reviews proposed and actual pesticide use in parks. The Risk Management Program provides policy, guidance, technical assistance to employees regarding safe work place practices, and tracks case incidence reports (tick bites, other) for recordkeeping and workers compensation purposes. The Wildlife Health Program provides technical and veterinary assistance to parks to identify and achieve wildlife health goals, and collaborates with the Public Health Program and other disciplines in NPS. The Human Dimensions Program assists park managers to

address the critical interface between the human and ecological dimensions of biological resource management.

F. National Institutes of Health (NIH)

Several institutes within the NIH support research on ticks and human tick-borne diseases, including Lyme disease. The National Institute of Allergy and Infectious Diseases (NIAID) supports the majority of both intramural and extramural research on tick-borne diseases, including Lyme disease, at the NIH. The NIAID research portfolio includes a broad range of research projects related to human TBDs, including microbiology, pathogenesis, immunology and vector biology; The National Institute of Arthritis and Musculoskeletal and Skin Diseases (NIAMS) focuses on research into the causes, treatment, and prevention arthritis, musculoskeletal, and skin diseases, including Lyme arthritis; The National Institute of Neurological Disorders and Stroke (NINDS) supports research to reduce the burden of neurological disease, including neurological Lyme disease; and the National Institute of General Medical Sciences (NIGMS) supports basic research to better understand life processes and lay the foundation for advances in disease diagnosis, treatment, and prevention. The National Human Genome Research Institute (NHGRI) in collaboration with NIAID supports multiple sequencing projects of microbes and their associated vectors that cause infectious diseases.

G. National Science Foundation (NSF)

The mission of the NSF is to advance fundamental scientific discovery and promote scientific education. As part of this mission, it has supported research on tick biology, and tick-borne diseases for many decades through many of its "core" programs. A targeted program, the Ecology and Evolution of Infectious Diseases (EEID), supports research on the ecological, evolutionary, and socio-ecological principles and processes that regulate the transmission dynamics of infectious diseases.

VII. Opportunities for Collaboration among Stakeholders

The TBD IPM WG determined that among the participating agencies a number of opportunities exist for potential synergistic collaboration given shared aspects of their missions and priorities. The following list organized according to areas of emphasis, contains initiatives of one or more agencies that are either currently underway or would be priority activities, contingent upon funding:

A. Healthy Ecosystems and the Impact on TBD Risk

1) Determine if intensive tick reduction can result in local elimination of *B. burgdorferi* transmission across different habitats and gradients of forest fragmentation.

2) Create life tables for *I. scapularis* to identify areas in need of more research and to prioritize IPM efforts. Life tables have been developed for various crop and forest pests, but are more difficult to conduct for multi host-ticks (i. e. species that require acquiring and feeding on three hosts to complete their life cycle). Important multi host-ticks include: *I. scapularis*, *A. americanum*, *Dermacentor variabilis, and Rhipicephalus sanguineus*).

3) Identify effective strategies to protect and enhance biodiversity and healthy ecosystems, including strengthening the expertise of landscape managers and planners.

4) Work with outdoor recreational park designers to create landscape plans that reduce human/tick interaction through deliberate designs that consider aspects of tick, host, environment, and human behavior/ecology.

5) Determine how landscape structure influences the effectiveness of different tick control strategies and identifying "landscape markers" that might suggest improved success of specific interventions.

6) Examine the relationship between management of invasive plants and reduction in tick habitat.

7) Assess impacts of ecological parameters (e.g., tick population and community dynamics; host population and community dynamics; environmental factors) on ticks and disease.

8) Conduct studies on the impact of ticks or tick-borne disease on wildlife populations in parks (important One Health component).

9) Enhance cooperation between urban planners, landscape architects, IPM specialists, wildlife disease ecologists, and public health programs, to ensure future developed areas are designed with tick ecology and human behavior in mind to reduce risks at initial design phase.

10) Understand further pathogen/tick interactions, including tick immunity, molecular interactions between pathogens and tick tissues, salivary gland invasion, and transmission.

11) Determine the effect of tick saliva on the vertebrate hosts' immune system and pathogen transmission.

12) Elucidate the ecological reasons for the present geographical distribution of Lyme disease in eastern North America and evaluate the potential link between tick distribution and climate change.

13) Conduct research on the roles of birds as reservoirs of Lyme spirochetes and identify potential natural enemies of ticks.

14) Enhance initiatives to evaluate pesticide products proposed to control ticks.

15) Develop a Tick IPM Strategic Plan that complements EPA's *Strategic and Implementation Plan for School IPM* to reduce risk to children, a known sensitive subpopulation, to tick-borne diseases.

16) Evaluate core research needs to address vector borne disease.

B. Impact of Deer density and Effectiveness of Deer Management Programs

1) Evaluate the role of deer density and deer management on tick abundance and Lyme disease incidence. Studies may include observational studies of community-level deer management in relation to Lyme disease incidence, as well as studies to correlate direct and indirect measurements of deer activity. The goal of these studies would be to provide evidence-based recommendations regarding management of white-tailed deer populations in the Northeastern U.S

2) Advise communities on effective deer-targeted tools such as the ARS-patented '4-Poster' Deer Treatment Bait Stations.

3) Investigate other potential methods under development for reducing tick abundance on deer, such as ivermectin treated baits and automated collaring devices.

C. Rodent-Targeted Control Efforts

1) Evaluate reservoir-targeted vaccines for Lyme disease prevention.

2) Evaluate rodent-targeted acaricides for control of ticks on residential properties.

3) Investigate antibiotic-laden baits for reduction of *Borrelia* and *Anaplasma* in rodents and ticks.

D. Improve Protection and Training Programs for Workers

1) Expand use of the "Tick Check" sheet that has been prepared by Exotic Plant Management Team, National Capital Region for field use by National Park Service employees and other field workers.

2) Provide guidance for state pesticide applicator certification and training programs on how to best prevent exposure to ticks that may carry pathogens. Complete revision of the pesticide applicator regulations supports this initiative.

3) Ensure field staff and other outdoor workers have access to personal protection information and materials (e.g., repellent) for reducing risk of tick-borne disease.

4) Evaluate possible use of pretreated (permethrin) uniform clothing for NPS field staff.

5) Increase and enhance training and scientific information provided to environmental health practitioners and other public health professionals engaged in tick control activities and outbreak response.

6) Develop and deploy permethrin-treated uniforms, in collaboration with Program Executive Office Soldier, US Army Natick Soldier Research, Development & Engineering Center, US

Army Public Health Command, Deployed War-Fighter Protection Program, USDA Center for Medical, Agricultural, and Veterinary Entomology.

7) Coordinate efforts to improve tick control on livestock with efforts to protect humans from tick bites. Examples of potential products developed for agriculture but with use for protection of humans are medicated bait blocks for animals, anti-tick vaccination of animals, improved repellent products, area-wide management of ticks, and new acaricides.

E. Improve Vector Surveillance, Risk Assessment, Risk Communication, and Effectiveness of Programs

1) Strengthen and refine a coordinated surveillance program for monitoring ticks that includes tick species data and tick infection rate by county.

2) Improve surveillance for NPS-associated tick-borne diseases using local data and enhanced data sharing tools with state and local health departments.

3) Evaluate how interventions applied to single properties versus clusters of adjacent properties influences the probability of Lyme disease case occurrence in persons residing in treated and neighboring untreated residences.

4) Complete genomic sequencing and gene annotation for tick species with greatest relevance to public health. Generate tick tissue culture systems that will advance the study of pathogen/tick interactions.

5) Develop molecular reagents that will enhance the study of tick-borne diseases.

6) Integrate laboratory-based molecular approaches and knowledge with field/ecological studies.

7) Continue to develop and maintain TickMap and other online, interactive tools for mapping worldwide tick abundance, distribution and pathogen prevalence.

8) Develop a Tick IPM Strategy to include a communication and outreach plan to reduce risk to tick-borne diseases.

9) Develop and distribute educational toolkits (web-based resources, trail signs, multi-lingual brochures, occupational risk information, etc.) to public health practitioners and the general public, to reduce exposure to ticks and tick-borne pathogens.

10) Establish a coordinated, online information clearinghouse on IPM resources that provides a reference center for IPM best practices.

11) Improve efficient targeting and integration of interventions in IPM programs.

VIII. Areas of Highest Strategic Priority

Recent decades have seen a dramatic expansion of research on tick biology, ecology and management. Consequently, numerous novel approaches to tick control have been devised. Several reviews of the scientific literature on tick management have been published in the past decade, including Stafford and Kitron (2002), Ginsberg and Stafford (2005), Piesman (2006), Ghosh *et al*. (2007), and Piesman and Eisen (2008). Furthermore, specialized areas of tick management have been reviewed, including biological control (Samish and Rehacek 1999, Samish *et al*. 2008), use of tick pheromones (Sonenshine 2008), anti-tick vaccines (Willadsen 2008), repellents (Bissinger and Roe, 2010) and acaricides (Graf *et al*. 2004, George *et al*. 2008). In addition, several practical guides are available for general information about tick biology, self protection and tick management, including the Tick Management Handbook (Stafford 2007), a guide to tick management professionals (Schulze and Jordan, 2006), the CDC web site (www.cdc.gov/ticks/), and the TickEncounter website (www.tickencounter.org). In this section we briefly synthesize the US federal efforts, and place them in the context of the broad-scale international research program to control tick-borne diseases of public health importance. Opportunities for greater coordination and collaboration among agencies are emphasized, and topics that deserve greater federal attention are identified. A recent review article on research needed to improve Lyme disease prevention (Eisen *et al*. 2012) provides a framework for our discussion of the roles of federal agencies in tick-borne disease research.

The collaboration of federal programs outlined in the previous pages make it clear that federal efforts operate on multiple levels: 1) basic research on transmission biology of tick-borne pathogens and applications for tick management (CDC, NSF, EPA, USGS, ARS, NIFA); 2) research on the nexus between natural cycles and human infection, and applications for public health protection (CDC, NIH, DOD); and 3) programs in agencies that do not have a primary research focus (such as land management agencies) that need information for management decisions and policy that require research support, as well as applications of management programs (FWS, NPS, DOD, APHIS).

A. Research Needs

A recent review article (Eisen *et al*. 2012) identifies several priority research areas to improve Lyme disease prevention. These include: 1) identifying critical host infestation rates required to maintain enzootic transmission; 2) understanding how habitat diversity and forest fragmentation affect acarological risk and effectiveness of interventions; 3) quantifying epidemiological outcomes of interventions focused on ticks or reservoir hosts; and 4) refining knowledge of how human behavior affects disease risk and how to foster adoption of personal protection measures and environmental management. Federal efforts to answer these questions can be optimized by fostering efficient integration of activities among agencies. The following table lists by category the federal agencies that are currently conducting or supporting research in these four priority areas. This table is not meant to identify the primary or secondary roles of the various agencies in tick-borne disease research, but rather to suggest areas of program compatibility where collaborations are likely to be fruitful.

Table 5. Agency Operational Levels and Tick-Borne Research Needs

Research Needs	Transmission Ecology	Human Infection	Management Needs

Critical Infestation Rates	NSF – EEID CDC USDA NIH	CDC NIH	DOI (NPS & FWS) DOD USDA
Habitat & Community Effects	NSF CDC USGS	CDC NSF EPA	DOI DOD USDA
Effectiveness of Interventions	CDC USDA NIH EPA	CDC DOD NIH	DOI DOD USDA
Human Behavior	CDC NIH	CDC NIH NSF	DOI DOD

B. Areas of Potential Collaboration Among Agencies

Basic research on the transmission ecology of human pathogens, at the levels of autecology, population, and community ecology, are funded for non-federal organizations (such as universities) by the NSF Ecology and Evolution of Infectious Diseases program and USDA, NIFA. Extramural research on the human disease aspects of this area is funded by the NIH. These agencies already coordinate their efforts in this focus area. The CDC utilizes basic research findings to advise intra- and extramural research at a more applied level, such as validation of specific interventions for public health protection. The USDA carries out a similar spectrum of activities related to domestic animal health, as does the USGS for wildlife health. These efforts are coordinated only intermittently and informally. From a One Health perspective, greater coordination of these efforts would be worthwhile, especially since the interactions of domestic animals and wildlife in human-influenced environments is a potentially important generator of tick-borne and zoometric disease outbreaks in the foreseeable future.

Several agencies perform research on tick-borne diseases, and also carry out interventions on their own lands or elsewhere. For example, DOD performs research on tick-borne diseases, and interventions on installations, training areas, and areas of troop deployment. DOI performs research (USGS) and management in national parks (NPS) and wildlife refuges (FWS). USDA performs research (ARS and NIFA) and applies research results on farms and in communities. Moreover identification of vector-borne disease risks and national tick surveillance activities are performed by APHIS. These agencies provide the potential for experimental application of results from basic and applied research, to lands that are closely managed and for which the histories are well known. Coordination of research efforts with land-management agencies would allow the opportunity for well controlled field trials of management interventions, as long as the interventions are compatible with permitted uses of the proposed research lands.

IPM for vector-borne diseases of humans has proven to be beneficial. Pest control interventions are required to follow IPM principles by several federal agencies. Further research in the specific area of management for natural resource protection generally follows " Adaptive

Management" principles, which recognizes that decisions are never made with complete knowledge of local conditions, so monitoring is performed to gather data that will allow improved management efforts in subsequent interventions. Current advances on approaches to management decision-making provide land managers with guidance for natural resource decisions, and could be applied to management of tick-borne diseases. Further coordination of federal efforts at decision-making for management of tick-borne diseases would be beneficial.

Information gathering and database management would benefit from greater coordination among agencies. The VectorMap program, originally begun with DOD, is now coordinating with Smithsonian and other agencies to gather and present geographic information about disease vectors, pathogens, hosts, etc. The CDC maintains geographic information about vector-borne diseases in the US, some of which is made available online at the CDC website, and at the USGS disease maps website. Coordination of federal geographic data gathering, archiving, and presentation would be a worthwhile goal.

Genomic and bioinformatics information and tools associated with tick genome(s) are available through VectorBase, a bioinformatics resource center supported by NIAID. As additional tick genomes are sequenced, VectorBase would add them to its database (www.vectorbase.org/). This web-accessible data is a repository for information about invertebrate vectors of human pathogens. VectorBase annotates and maintains vector genomes providing an integrated resource for the research community. Currently, VectorBase contains genome information for several organisms including *Ixodes scapularis* which may carry pathogens causing tick-borne diseases.

Research about human behavior and transmission risk of tick-borne diseases is broadly recognized as an area that requires considerably more attention. Basic research in this area, and applicability to prevention of tick-borne diseases, deserve additional federal effort.

C. Potential Initiatives To Measure Success

The US government is required to measure success of research and provide guidance to develop effective tools to reduce risk from tick-borne disease. The following initiatives were identified as potential IPM programs to reduce risk and provide measurements of success and timeline for each.

1) Develop a National Inventory of Tick Monitoring and IPM

The TBD-IPM workgroup has initiated development of an inventory of tick monitoring and tick IPM efforts to prevent TBD. This well-organized survey includes a bibliography of all scientifically peer reviewed tick monitoring and IPM research conducted by federal, state, local government agencies and academia and other stakeholders. During this development, the TBD-IPM workgroup is identifying research initiatives and extrapolating how this research provides appropriate IPM tools for all regions in the Unites States, as well as identify areas where we can reduce research and IPM efforts when it already exists. This inventory will support TBD-IPM WG existing relevant federal databases. This survey will be completed by 2014.

2) DEVELOP AN INFORMATION CLEARINGHOUSE TO SUPPORT EDUCATION, OUTREACH AND COMMUNICATION EFFORTS

A number of educational and outreach resources, and toolkits have been developed by federal, state, and local government agencies and by universities and other stakeholders that contain reliable prevention information targeted toward different risk groups. While these educational tools are available for download from various websites or are distributed upon request, there is no single place where they are referenced. As a result, they are not as well accessed and utilized as they could be. Establishment of a well-organized, single domain for up-to-date and reliable information would be highly useful both for advertising their presence and for reducing efforts at developing tools that already exist – 2014.

3) DEVELOP A DECISION SUPPORT MODEL FOR COST-EFFECTIVENESS OF PREVENTION

This decision support model would guide decision makers in implementing cost effective prevention programs (including cost and effectiveness measures). This would require quantifying epidemiological outcomes of interventions focused on ticks or reservoir hosts – 2015.

4) DEVELOP PREDICTIVE MODELS

These predictive models should be based on appropriate research tools and data, and should be used to indicate areas of emerging disease risk. Implementation plans would include education and outreach to physicians and other healthcare providers for awareness when assessing patients for potential vector borne disease or other illnesses – 2015.

5) DEVELOP A DECISION SUPPORT MODEL FOR COST-EFFECTIVENESS OF PREVENTION

This decision support model would guide decision makers in implementing cost effective prevention programs (including cost and effectiveness measures). This would require quantifying epidemiological outcomes of interventions focused on ticks or reservoir hosts – 2015.

6) DEVELOP HABITAT ANALYSIS STRATEGY

The strategy would determine how habitat diversity and forest fragmentation affect acarological risk and effectiveness of interventions – 2015

7) DEVELOP STRATEGY FOR EFFECTIVELY CONTROLLING VECTOR TICKS

Identify important areas of potential tick exposure based on landscaping or topographical features or existing surveillance data (e.g. schools, residential areas, outdoor recreational facilities, etc.). Target these areas for implementation and evaluation of both currently-available and novel control strategies. Develop an operative model that would involve multi-level collaboration between federal, state, and local agencies, working together to prevent exposure to vector ticks – 2016.

8) FEDERAL RESEARCH INITIATIVES

Develop guidance to federal research programs to integrate basic, applied and field studies. This research would identify critical tick density and host infection rates required to maintain enzootic transmission – 2016

IX. AGENCY ACCOMPLISHMENTS

The following accomplishments were submitted by each agency, providing some specific examples of how that agency views the application of its mission with respect to TBDs. These lists are not comprehensive for all agencies. For agencies with broader health mandates on TBDs, the activities are limited to those that relate specifically to IPM. In some cases, limitations on resources have resulted in prioritization and subsequent reduction in activities, which otherwise would be provided.

A. CENTERS FOR DISEASE CONTROL AND PREVENTION (LIMITED TO RECENT IPM-RELATED ACTIVITIES, ONLY)

The following initiatives have been completed or are in progress:

- Demonstrated field efficacy of rodent targeted bait boxes with fipronil wick for reducing tick vector abundance and infection rates, and completion of a commercial licensing agreement for private sector distribution.
- Worked with an industry partner to develop and evaluate in laboratory animals a rice-expressed, Osp-A-based host-targeted Lyme disease vaccine.
- Worked with university partners and industry to conduct field evaluation of an *E coli*-expressed, OspA-based host-targeted vaccine directed toward rodent reservoirs of *Borrelia burgdorferi*.
- Demonstrated the efficacy for controlling ticks and the novel mode of action for a new group of food-grade natural product insecticides that CDC developed and patented.
- Published national guidelines on the diagnosis and management of TBDs as an MMWR: www.cdc.gov/mmwr/preview/mmwrhtml/rr5504a1.htm. An update is planned for 2013.
- Initiated the TickNet program in 19 states and conducted a placebo-controlled trial in three TickNet sites to determine effectiveness of a single springtime application of

acaricide in residential yards to prevent Lyme disease and other tick-borne infections in humans.

- Launched an enhanced communication plan and prevention toolkit to improve public awareness and knowledge. The tool kit includes multilingual brochures, trail signs, public service announcements, and website enhancements.

- Created a course ("Biology and Control of Public Health Pests: The Importance of Integrated Pest Management.") focused on IPM for insects and rodents that contains a module specific to concepts of tick control. To date, over 500 attendees have taken course at 9 locations throughout the US and over 15,000 sites from around the world have registered for the online version of this popular course.

- Identified *Rhipicephalus sanguineus* as the primary vector of *Rickettsia rickettsii* in eastern Arizona during an RMSF outbreak with multiple fatalities. The problem is ongoing and CDC has worked with the Native American population, tribal officials, state health department, and Indian Health Service to advance knowledge and reduce risk of exposure.

- In collaboration with state, federal, and local partners, implemented a 6-month pilot study in AZ using IPM (tick collars, environmental treatment, spray/neuter free-roaming dogs) that reduced *R. sanguineus* infestation of dogs from >30% to <1%.

- Hosted a multi-agency conference at CDC-Atlanta on ticks and tick-borne diseases in the southeastern United States.

- Developed educational materials for outdoor employers and workers including Web materials and a NIOSH Fast Facts card.

- Funded two, multi-year cooperative agreements with university partners for field evaluation of novel tick control IPM methods.

B. US Department of Agriculture

1) Agricultural Research Service

Although the primary mission of the USDA Agricultural Research Service is agriculture, ARS has made significant contributions both historically and recently toward the control of tick-borne diseases of humans. Much of that progress has been a direct spin-off of efforts to control ticks associated with livestock. Accomplishments include the

following, which includes major historical achievements representing the long-term effort of research in this area by USDA:

- In 1879, USDA's Theobald Smith proved that the cattle fever tick transmits *Babesia* to cattle, which was the first proven case of any arthropod-transmitted pathogen. That discovery was the basis for description of the many other tick-pathogen associations found in the decades to come.

- Treated uniforms for the military were first developed by USDA in the 1940s in response to the threat from chigger-borne rickettsioses (scrub typhus). Use of dimethyl phthalate, ethyl hexanediol, and other ingredients were found to give good protection against the chiggers in Asia that transmitted the rickettsiae, giving American troops a significant advantage over the enemy at a time when scrub typhus was an untreatable disease.

- After the war, USDA developed a mixture of chemicals called M-1960 that became the standard clothing treatment up to the war in Vietnam.

- The current clothing treatment consisting of permethrin was developed with significant input from ARS, culminating in the adoption of this uniform treatment in 1990. It is still the standard treatment of uniforms in the US military, providing considerable protection against ticks. Permethrin treatment of clothing is currently available for civilians, as well. ARS continues to develop methods for and evaluate permethrin treatment of uniforms.

- USDA ARS invented DEET in the late 1940s and continued to develop its use in subsequent decades. Recent quantitative tests of its effectiveness against ticks have shown that other active ingredients can provide longer-lasting protection against some ticks; however, DEET remains a useful repellent for this purpose, especially since it is easily available and commonly used by the public. Personal protection from tick bites should be an important element of IPM.

- Developed the "4-poster" device for treating cattle and deer for ticks. USDA ARS developed this device and demonstrated that its correct use can reduce the abundance of the Lyme disease pathogen in large areas. The device is available commercially and is used by some communities in an effort to reduce Lyme disease incidence.

- USDA ARS has capabilities that could be used extensively to promote tick control for prevention of human disease. One small example was the successful encapsulation of a volatile acaricide, nootkatone, developed by CDC. Using technology developed for application of pheromones, ARS successfully encapsulated nootkatone in a lignin-based formulation and demonstrated that it could extend the effectiveness of the compound. That study was conducted jointly with CDC and the Connecticut Agricultural Experiment Station. Current work by ARS on the development of RNAi insecticides and natural products might be usefully extended to ticks.

2) Animal and Plant Health Inspection Service

APHIS is engaged in conducting surveillance, risk assessments, and animal treatments for ticks on imported and domestic livestock and wildlife. These exotic and domestic tick species are considered potential vectors of tick-borne diseases of humans, such as Lyme disease, babesiosis, and anaplasmosis.

- APHIS provides tick diagnostic services through the National Veterinary Services Laboratories in Ames, Iowa. The National Veterinary Services Laboratories provides identification of tick specimens from anywhere in the world (e.g., from ports of entry), and these diagnostic services support tick surveillance and eradication programs within APHIS.APHIS provided funding for the completion of the first comprehensive larval identification guide for 58 Ixodid tick species in the US, which is a cooperative effort by Georgia Southern University and APHIS' National Veterinary Services Laboratories.

- APHIS provides funding for the "Exotic Arthropod Surveillance in the Southeastern US and Puerto Rico" cooperative agreement with the Southeastern Cooperative Wildlife Disease Study (SCWDS), which is affiliated with the University of Georgia, to identify potential vectors of equine piroplasmosis on wildlife in South Texas and to detect exotic species of ticks on wildlife in the southeastern US.

- APHIS maintains a tick geodatabase that is housed and maintained at the Center for Epidemiology and Animal Health in Fort Collins, Colorado. The foundational data sources for the tick geodatabase are the NVSL tick surveillance data and the United States Tick Collection from the Smithsonian Institution. County-based distribution maps have been produced for 15 tick species in the US based on data from our tick geodatabase.

- APHIS continues to work on a national tick distribution survey, which is ongoing with National Animal Health Network to identify laboratories in each state that can provide tick identification services and tick diagnostic tests. Ten new tick distribution datasets have been received from various states across the United States. They will be incorporated into our tick geodatabase during this next year.

- APHIS has developed tick habitat based models for the American dog tick and the Cayenne tick to predict the potential distribution of these equine piroplasmosis vectors within the US for tick surveillance and mitigation activities. APHIS has completed tick Risk Assessments and biological descriptions on tick vectors of heartwater, cattle fever, and equine piroplasmosis.

- APHIS, CDC, and NEON (National Ecology Observatory Network, funded by the National Science Foundation) are currently collaborating on developing county-based distribution maps for the lone star tick in the United States. APHIS continues a long-term collaboration with NEON on distribution of medically and veterinarily important tick species in the US. APHIS collaborates with state veterinarians on a project by project basis for a variety of vector-borne diseases in the US.

- APHIS' National Wildlife Research Center has conducted seven studies focusing on issues relating to risk of cattle fever tick to US agricultural interests or control cattle fever tick. These include: effects of microclimate changes in different vegetation types on cattle fever tick larval survival; using sentinel cattle to monitor tick populations after oral and topical acaricide treatment on white-tailed deer; integration of ecologically-based approaches to re-eradicate cattle fever ticks from the US; movement and habitat use of nilgai antelope in southern Texas; fever tick land use survey in southern Texas and northern Mexico; bovine tuberculosis and other feral swine diseases in the Texas border region; and fever ticks from exotic ungulate wildlife in northern Mexico.

3) NATIONAL INSTITUTES OF FOOD AND AGRICULTURE

USDA, NIFA has funded research and extension (outreach) projects thorough a number of different NIFA programs: Hatch Formula (Capacity Building) Funding,, Animal Health Grants, Special Grants, Small Business Innovation Research Grants, McIntire-Stennis, Smith Lever (3D) Grants, NRI Competitive Grants, and AFRI Competitive Grants. Current and recent projects funded by NIFA can be accessed by using the USDA, Current Research Information System (CRIS) search engine. Web based initiatives are identified by their websites in the Web Page Section of this document.

- NIFA collaborates with NSF on the Ecology and Evolution of Infectious Diseases (EEID) program. See: www.nsf.gov/funding/pgm_summ.jsp?pims_id=5269

- NIFA provided funding for development of the TickEncounter website and basic and applied research for development of several of the site's knowledge functions. See: www.tickencounter.org/

- The TickEncounter Resource Center promotes tick-bite protection and tick-borne disease prevention by engaging, educating, and empowering people to take action.

- The TickApp: ***The TickApp*** for Texas and the Southern Region has been developed to provide citizen consumers and professional practitioners with a convenient guide to the identification of ticks impacting humans, livestock, companion animals, and wildlife. ***The TickApp*** also provides educational information on tick biology, association of disease causing pathogens, prevention and protection, and control and management. Delivery of this information through smart phones and other similar devices is intended to reach consumers and practitioners quickly and conveniently when and where it is needed most in field, home, clinical or client-based settings.

- NIFA support extension, an online national extension outreach effort organized around Communities of Practice (CoPs). Several CoPs have produced tick information fact sheets on detection, prevention, and IPM and have an "Ask the Expert" feature. See www. extension.org for the extension "Search" function and Resource Areas for Communities of Practice.

- Through funding to the Regional IPM Centers, NIFA has supported development of Regional Pest Alerts:
  - Pest Alert for the Brown Dog Tick. See: www.ncipmc.org/alerts/browndogtick.cfm
  - Rocky Mountain Spotted Fever. See: www.ncipmc.org/alerts/rmsf.cfm

- Examples of other NIFA funded projects include:
  - Monitoring Medically Important Arthropods and Associated Infections.
  - Studies of tick-borne Disease Agents in the Far-Western United States.
  - Tick-Host-Landscape Ecology Effecting Human and Animal Health.
  - Mosquito- and Tick-Borne Disease Surveillance in Iowa.
  - Tick Midgut Epithelial Tissue and Macrophage Migration Inhibition Factor (MIF): Targets for Developing Anti-Tick Vaccines.
  - The Ecological Effects of fire on the Distribution and Dynamics of Tick-Borne Zoonoses.
  - NIFA funds a significant portion of the IR-4 Project (see IR-4 below).

4) IR-4 USDA

The IR-4 Project Public Health Pesticides Program has undertaken a number of activities focusing on IPM approaches for control of tick-borne diseases:

- Published an Inventory of Public Health Pesticides (2012), which includes a chapter on tick control, with tables of tick repellents and tick toxicants registered in the US and elsewhere.

- Developed an online Public Health Pesticide Database (ir4.rutgers.edu/PublicHealth/publichealthDB.cfm) that allows open access to information on toxicant and repellent attributes, efficacy, and regulatory status

- Is collaborating with the DOD on risk assessments for the potential retreatment of pretreated military uniforms, which could extend the useful life of tick repellent garments.

C. US Department of Defense

In an effort to provide better protection for Soldiers against a wide variety of arthropod-borne diseases, the Army began issuing Army Combat Uniforms that are factory-treated with permethrin (ACU with Permethrin), starting in October 2012. Wearing permethrin-impregnated clothing is a vital part of the DOD Insect Repellent system keeping US Service members protected from vector-borne disease while serving in CONUS and OCONUS garrison and field environments.

Factory treatment of uniforms has long been recognized as the most efficient way to protect soldiers. Several attempts have been made since 1987 to implement factory treatment, but none were completed due to lack of contract implementation and/or funds cancellation. The Army Uniform Board (AUB) has approved factory treatment at least twice since 1987, most recently in December 2008.

Since 2010, the Army has been fielding the Fire Resistant ACU with Permethrin in Iraq and Afghanistan. Experience has demonstrated that wearing permethrin factory-treated uniforms was far more effective than having Soldiers individually treat their uniforms with permethrin spray or kits.

The Army is providing the best possible products available to enhance Force Health Protection and Readiness. The introduction of the ACU with Permethrin will provide soldier protection from insect and tick borne diseases, while in garrison and training environments throughout the world in non-combat situations. By providing ACU with Permethrin to all Soldiers, the guesswork as to who has and who does not have a permethrin-treated uniform is removed. Soldiers must be prepared to perform their duties at anytime and anywhere in response to field training, garrison environments such as working in the motor pool, and Disaster and National Response incidents in high risk vector borne disease areas. The ACU with Permethrin will ensure that Soldiers are protected from vector-borne diseases at all times. Most importantly, the decision to issue ACU with Permethrin to all Soldiers was made only after the factory treatment of uniforms was assessed for safety and repellency in the laboratory.

The Army has used permethrin for over 20 years to treat soldiers' uniforms, compiling an excellent safety record with Soldiers. The EPA, the National Academy of Sciences, the US Army Surgeon General, and the Commandant of the US Marine Corps have all approved permethrin treatment of clothing. Since March of 2007, the US Marine Corps has issued only factory-treated Marine Corps Combat Utility Uniforms.

1) US Army Public Health Command

- Since 1991, the US Army Public Health Command (USAPHC) has had a mandate (via Army Regulation 40-5) to establish a DOD-wide Lyme Disease Program as well as provide services and programs to prevent other tick-borne diseases that impact the military community. These efforts include:

- DOD Human Tick Test Kit Program (HTTKP) which includes the identification of ticks and testing for pathogens in ticks that are removed from military personnel. The HTTKP provides an easy-to-use specimen container/mailer provided to military medical practitioners and has served more than 30,000 tickbite victims over nearly 20 years. Participation in the HTTKP keeps military medical personnel informed about tick-borne diseases which are rapidly evolving as tick populations are expanding and new pathogens are being discovered.
  phc.amedd.army.mil/topics/envirohealth/epm/Pages/HumanTickTestKitProgram.aspx

- Vector Test Kit (VTK): Pathogen analysis of ticks and other parasitic vectors collected from euthanized feral animals (primarily dogs) as part of troop health protection efforts

during deployment operations. This is done via the use of a Vector Test Kit (VTK) provided to deployed veterinary specialists and results in the attainment of regional pathogen risk data.

- Pathogen analysis of ticks removed from military working dogs and submitted by military veterinary collaborators.
- Consultations and training by subject matter experts on entomology related procedures, practices, surveillance methods, protective measures, and health issues associated with ticks.
- Quick response investigations and health threat assessments caused by emerging and range-expanding tick populations impacting military installations.
- GIS mapping and risk analysis associated with tick populations on military installations.
- Special projects supporting tick identifications and disease analysis for deployed troops.
- Army Vector-borne Disease weekly report. This is a publicly available, electronic summary of selected vector-borne diseases from Army personnel and results from vector-surveillance performed on military installations. Intended for public health personnel, preventive medicine personnel, and clinicians. The report is available at:. phc.amedd.army.mil/Periodical%20Library/ArmyWeeklyVector-borneDiseaseReport_25Sep12.pdf
- Specialists participate in interagency working groups and panels to further the knowledge on national tick-borne diseases and to find solutions for human and animal risk reduction.

2) Armed Forces Pest Management Board

The AFPMB's mission is to ensure that environmentally sound and effective programs are present to prevent pests and disease vectors from adversely affecting DOD operations. In support of this mission, the Armed Forces Pest Management Board:

- Develops and recommends policy to the Under Secretary of Defense for Acquisition, Technology and Logistics.
- Coordinates pest management activities in the DOD.
- Develops issues, and maintains manuals and other guidance necessary to implement the technical requirements of the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA).
- Implements the DOD plan for Certification of Pesticide Applicators and develops comprehensive training guidance for DOD pest management personnel.

- Coordinates DOD contingency disease vector and pest management with the Joint Staff, the Combatant Commands and other contingency planning organizations.
- Serves as an advisory body to the DOD Components and provides timely scientific and professional pest management advice.
- Develops and distributes technical information and guidance on pest management to the Components by means of Technical Guides, Disease Vector Ecology Profiles and similar publications.
- Reviews and approves any introduction and deletion of pest management materiel (excluding disinfectants and biocides) by the Defense Logistics Agency (DLA) in the DOD supply system.
- Coordinates and develops requirements for pest management research, development, testing and evaluations in the DOD.

Specific tick related efforts include:

- Literature Retrieval System: complete archive of articles on tick-borne disease.
- Developed a DVD on tick morphology and identification.
- Development and deployment of permethrin-treated uniforms, in collaboration with Program Executive Office Soldier, US Army Natick Soldier Research, Development & Engineering Center, US Army Public Health Command, Deployed War-Fighter Protection Program, USDA Center for Medical, Agricultural, and Veterinary Entomology.
- A website-based photo gallery of ticks is publicly available in the "Flickr Images" database via a link on the right-hand side of the AFPMB home page. That currently includes >75 good quality images.

3) THE DEPLOYED WAR FIGHTER PROTECTION PROGRAM (DWFP)

The DWFPP is an ongoing small grant program (including competitive grants) that was developed in 2004 and has been renewed annually since then. In most years, the total funding has been around $5 million. Its intent is to foster and help fund start-up type basic and applied research projects that address needed research toward protecting deployed DOD personnel from vector-borne diseases. So far, there have been at least 16 technical articles published in scientifically peer reviewed journals that included a tick species as the study subject. Many of the studies addressed repellents or tick biology. A PDF of each of those is publicly available by selecting the "publications" link at the bottom of the pull-down menu under "DWFP" at the top of the AFPMB home page. Walter Reed Army Institute of Research (WRAIR).

- TickMap, an online, interactive tool for mapping worldwide tick abundance, distribution and pathogen prevalence. www.tickmap.org

- The Walter Reed Biosystematics Unit (WRBU). Worldwide arthropod vector species identification in collaboration with US Natural History Museum.

4) ARMED FORCES HEALTH SURVEILLANCE CENTER

- MSMR, Medical Surveillance Monthly Report, which includes reporting of cases on tick-borne disease among military patients. www.afhsc.mil/msmr
- Annual Lyme Disease Report. www.afhsc.mil/viewDocument?file=VectorBorneReports/LymeDzAnnualReport2001-2010final.pdf
- Defense Medical Epidemiology Database. Users may perform queries regarding disease - including vector-borne disease rates in military populations. www.afhsc.mil/aboutDmed

5) NAVAL MEDICAL RESEARCH CENTER

- Rickettsial Diseases Department. www.med.navy.mil/sites/nmrc/Pages/id_rd.htm
- Development of molecular assays for detecting rickettsial and other tick-borne pathogens.
- Identification of novel tick-borne pathogens.
- Critical reagent program or homeland security forensic reagent program: Rickettsial Diseases Department maintains one of the largest collections of various rickettsial pathogens in the world.
- Naval Infectious Diseases Diagnostic Laboratory (NIDDL), a new DOD clinical reference laboratory established to clinically diagnose infectious diseases of military importance such as rickettsial and other tick-borne human diseases.

D. US ENVIRONMENTAL PROTECTION AGENCY

1) OFFICE OF PESTICIDE PROGRAMS

- Established an ongoing relationship with the Lyme Disease Association through the Pesticide Environmental Stewardship Program. As part of this partnership, the Lyme Disease Association developed and executed a strategy that resulted in the formation of a network that included local, state, federal, non-profit organizations and academia. Related communications, through the National School Nurses Association, facilitated the delivery of a newsletter article on tick IPM to over 20,000 school nurses.
- Convened a 2011 conference, *Community IPM for Tick Vectors*, with more than 250 attendees. Outcomes of the conference included increased public awareness, new and

strengthened partnerships with many organizations, and a federal research strategy that was initiated to improve IPM for prevention of TBD.

- Established along with CDC in the aftermath of the 2011 Community IPM for Tick Vectors conference, the inter-agency Tick-Borne Disease Integrated Pest Management Workgroup (TBD IPM WG), a subgroup of the Public Health Pesticide Consortium.
- Co-lead the TBD-IPM WG with the CDC. Agency TBD-IPM WG members include: USDA (ARS, NIFA, APHIS, IR-4 Program, USFS); DOD, US Army (WRAIR) and AFPMB; HHS (CDC and NIH); NSF; DOI (USGS, NPS, USWS); and EPA (OPP, ORD, OSA, Region 1), This federal workgroup creates a forum for communication and collaboration among US federal agencies involved in tick control as it relates to human health and to companion animals and wildlife that may serve as potential zoometric reservoirs.
- Co-sponsored TBD-IPM workgroup March 5-6, 2013 conference which brought together representatives from numerous federal, state and local agencies, academia, and stakeholders to discuss the current state of IPM for the management of tick-borne diseases. The first day was limited to federal partners only with all 14 agencies presenting. The goal for day 1 was to finalize this white paper document, and identify next steps. The second day, open to the public, included the keynote speaker, Dr. David Walker, UTMB and guest Dr. Willy Burgdorfer, NIH emeritus, who discovered *Borrelia burgdorferi,* the pathogen which causes Lyme disease. A total of 17 presentations on tick-borne diseases and IPM.
- In response to issues raised by federal partners on March 5, 2013 TBD-IPM conference, EPA and the TBD-IPM workgroup have initiated development of the National Survey of Tick Monitoring and Tick IPM efforts to Prevent TBD. This well-organized survey includes a bibliography of all scientifically peer reviewed tick monitoring and IPM research conducted by federal, state, local government agencies and academia and other stakeholders. During this development, the TBD-IPM workgroup is identifying research initiatives and determining appropriate IPM tools for all regions in the Unites States, as well as identify areas where we can reduce research and IPM efforts when it already exists. Coordination with existing federal databases is included. An additional benefit to this survey effort has been the facilitation of a more robust collaboration effort with all levels of federal, state, local government agencies, universities, and stakeholders to identify tick monitoring and effective Tick IPM tools.
- Continued support, in collaboration and strategic partnerships with local, state, and federal organizations, IPM approaches to reduce the risk of tick-borne diseases. OPP is evaluating prevention methods that include: (1) incorporating messaging into its school IPM program framework, (2) exploring partnerships with landscaping and habitat management organizations to reduce tick friendly areas, and (3) investigating opportunities to better protect worker in areas where ticks are prevalent.
- There are over 2,210 pesticide products and 92 active ingredients currently registered by EPA to control or repel ticks (NPIRS 2013). These products are classified as either conventional pesticides or biopesticides, depending on their mode of action and other factors. Since 1996, OPP, through its Biopesticides and Pollution Prevention Division, has fostered the registration of over 68 biopesticides to control (repel or kill) ticks. The

remaining 2142 products are conventional pesticides registered to control (repel or kill) ticks.

2) Office of Research and Development

- Developed an Ecosystems, Biodiversity and Human Disease initiative; co-sponsored a workshop with Region 1 on September 22-23, 2009 to develop a Community of Practice on Biodiversity, Landscape Change, and Human Health; awarded research grants and interagency projects on links between anthropogenic stressors, biodiversity, and disease transmission; and implementation planning and community of practice were developed with Regions.
- Developed statistical models of human exposure risk for endemic regions of Maryland and Pennsylvania. These explain most of the variability in Lyme disease incidence rate using a measure of forest habitat edge. Constructed a map-based decision tool for evaluating high- and low-risk neighborhoods under alternative development scenarios (with USGS Chesapeake Bay Office).
- EPA Region 3 and the New England Regional Office have recognized TBD as a risk and are collaborating with ORD on several projects including items listed in the previous bullets.
- Awarded a 2010 Regional Applied Research Effort (RARE) Grant to Region1 and ORD Narragansett Laboratory to evaluate the use of 4-Poster Deer Feeding Stations on Cape Cod and the Islands. The grant was supplemented with additional funding to continue the research through the 2013 and 2014 seasons.

3) Office of Air and Radiation - Climate Change Division

- Examined the peer reviewed scientific literature to better understand the links between the distribution of Lyme disease, climate factors and the potential impacts of climate change.

E. US Department of the Interior

1) US Geological Survey

Recent research efforts have included studies on the roles of birds as reservoirs of Lyme spirochetes, practical and theoretical aspects of targeted IPM programs for tick-borne pathogens, natural enemies of ticks, and distributions of tick-borne pathogens in various tick and wildlife species. Technical consultations and informational reports have been provided to national parks on the biology and management of ticks and tick-borne pathogens.

Research on wildlife diseases, including tick-borne zoonoses with implications for human health, remains a focus of the Wildlife: Terrestrial and Endangered Resources Program of the Ecosystems mission area within USGS, and of the National Wildlife Health Center.

2) National Park Service

National Park Service policy directs the use of IPM to reduce risks to people, resources, and the environment, from pests and pest related management strategies. Several programs coordinate to address tick related concerns in parks. The NPS IPM Program provides policy guidance, IPM training, technical assistance, and tracks proposed and actual use of pesticides. The NPS Office of Public Health conducts disease surveillance, investigates outbreaks and assists park managers in evaluating and improving visitor protection. The Office of Risk Management establishes policy, goals, and guidelines that affect all employees working in NPS properties, track case incidence reports (tick bites, other) using the Safety Management Information System (SMIS) for liability and worker compensation, and provides Operational Leadership training for all NPS staff to promote thinking ahead to evaluate risks and to be prepared associated with working in tick-borne disease areas. The NPS Wildlife Conservation Program is interested in the implications of tick-borne diseases for the conservation of wildlife at the landscape level, including migratory species. The NPS Wildlife Health Branch provides policy guidance to manage health issues associated with native and nonnative wildlife, professional and scientific consultation, technical assistance, veterinary expertise and research on wildlife disease. The NPS Human Dimensions Program examines people's values and desires related to biological resources and associated management actions. Human dimensions inquiry fosters improved human health and resource management in parks, and can enhance acceptability of biological resource management decisions.

The NPS accomplishments include:

- Protocols have been developed to conduct systematic building assessments to limit transmission of tick-borne relapsing fever at the North Rim of Grand Canyon National Park.

- Techniques to rodent-proof buildings have been published in the *The National Park Service Rodent –Exclusion Manual, Mechanical Rodent Proofing Techniques-A Training Guide for National Park Service Employee* www.nps.gov/public_health/info/eh/.../NPS_RP_Manual_v2.pdf. These exclusion efforts have effectively reduced rodent and arthropod vectors in lodging at Grand Canyon NP and other national parks.

- Efforts are underway to incorporate changes in contract design specifications and structural renovations to prevent /eliminate access of rodents and other tick hosts.

- Various outreach materials (e.g. education, tick identification, disease risk reduction) have been produced for wayside exhibits and brochures at specific parks.

- A "Tick Check" sheet has been prepared by Exotic Plant Management Team, National Capital Region for field use.

- A repellents document (draft) for parks has been drafted for park employees (based on EPA and CDC guidance).

- Education and outreach informational items have been prepared for park staff and visitors. This empowers non-biologists to be confident and accurate when explaining self-protection measures to visiting public.

- Developed a model employee tick education program to increase knowledge of common exposure habitats, work practice controls, and use of personal protective equipment.

- In collaboration with CDC, conducted (a.) an employee serosurveillance study for >10 zoometric and tick-borne diseases at Great Smoky Mountains NP and Rocky Mountain NP and (b) assessment of Colorado tick fever risk at Grand Teton NP.

- Conducted one-time monitoring for ticks and tick pathogens at Gettysburg NMP, Indiana Dunes National Lakeshore, Voyagers NP, and Yellowstone NP.

- Established a cooperative agreement with the California Department of Public Health to provide vector-borne disease surveillance (e.g. rodent trapping, tick flagging, pathogen and antibody testing) at the 26 national park units in California, including Yosemite NP and Golden Gate National Recreation Area.

- Implemented voluntary annual employee serosurveillance program for field employees at Fire Island NS.

- Conducted National Capital Region IPM Program tick surveys in collaboration with USDA ARS Beltsville Manassas National Battlefield, Greenbelt Park, and Rock Creek Park.

- Coordinated with various county health departments nationwide to develop mechanisms for conducting pathogen testing in ticks.

- Collaborated with state/local health departments and the CDC to respond to >25 reports of tick-borne diseases (confirmed or suspected) in employees and visitors, including Rocky Mountain spotted fever, Lyme disease, tularemia, ehrlichiosis, and relapsing fever.

- Provided technical assistance and consultation to park IPM coordinators, park managers and other employees, volunteers, partners, and visitors.

- Developed “Safe Work Practices for Employees Handling Wildlife”, including sections on vector control precautions and other safety measures.

- Supported employee trainings at multiple national parks, including Golden Gate NRA, Greenbelt Park, Yosemite NP, Valley Forge NHP, and National Capital Region Parks

- Hosted tick/vector educational booths at Bioblitz festivals at Biscayne NP, Indiana Dunes National Lakeshore, Saguaro NP, and Rocky Mountain NP.

- Provide IPM Principles Courses to NPS employees providing information on tick-borne diseases and hands-on field sessions on tick monitoring.

F. NATIONAL INSTITUTES OF HEALTH

NIH has conducted intramural research on ticks and tick-borne diseases for nearly a century at NIAID's Rocky Mountain Laboratories (RML) in Hamilton, Montana. RML maintains colonies of five species of ticks for basic and translational research on ticks and tick-borne bacteria, viruses, and rickettsia. Clinical studies are conducted at the NIH Clinical Center in Bethesda, Maryland, where more than 400 volunteers are enrolled in ongoing protocols to improve understanding and diagnosis of Lyme disease.

Tick- borne disease research at NIAID RML. See:
www.niaid.nih.gov/LabsAndResources/labs/aboutlabs/lzp/Pages/default.aspx

Lyme disease research at NIAID. See:
www.niaid.nih.gov/topics/lymeDisease/research/Pages/labs.aspx

NIAID's extramural TBD research portfolio resides primarily within the Division of Microbiology and Infectious Diseases (DMID). The Vector Biology Program supports basic research on arthropod vectors of diseases in humans. Research focusing on tick biology, tick-pathogen interactions, and tick-host interactions is supported by this Program, as well as basic research to support the development of vector management approaches such as traps, repellents and acaricides. The following initiatives are currently supported:

- NIAID is supporting tick research related to tick feeding regulation, saliva protein inhibitors, signaling pathways for tick salivary secretions, development of paratransgenic ticks for disease control, the tick olfactory system, and systematics of *Dermacentor* spp. Other tick species on which research is being conducted include *Ixodes scapularis* and *Amblyomma americanum*.

- The NIAID Lyme disease research program is primarily focused on the study of basic biology and pathogenesis of *Borrelia burgdorferi.* The research program also funds a diverse array of applied research projects aimed toward development of new diagnostic and vaccine targets. Current areas of investigation include studies of persistence of infection after antibiotic treatment using a variety of animal models and improvement of Lyme disease diagnostics.

- The Rickettsial and Related diseases program supports work that focuses on the biology and transmission of Rickettsia, Ehrlichia, and Anaplasma species.

- The Emerging Viral Diseases Program is supporting research on tick-borne virus ecology in the US (Powassan/Deer Tick virus) as well as R&D relating to TBE vaccines.

- Through n NIAID contract, The World Reference Center for Emerging Viruses and Arboviruses provides reagents and support for virus research and investigations of virus outbreaks throughout the world. Reagents are available to researchers worldwide and include many viruses that have been isolated from ticks in the US. (Please see the following link for more information: www.niaid.nih.gov/labsandresources/resources/dmid/wrceva/Pages/default.aspx).

- The Genomic Sequencing Centers for Infectious Diseases (GSCID) provide services for rapid and cost efficient production of high-quality genome sequences and high-throughput genotyping of NIAID Category A-C priority pathogens, microorganisms responsible for emerging and re-emerging infectious diseases and their hosts, related organisms, clinical isolates, and invertebrate vectors of infectious diseases. More info: www.niaid.nih.gov/labsandresources/resources/dmid/Pages/default.aspx.

- A tick genome sequencing project has been approved by the National Human Genome Research Institute (NHGRI) and NIAID. Information on this project can be found in the following link: www.genome.gov/26525388. The target species include *Ixodes scapularis, I. pacificus, I. ricinus, I. persulcatus, Dermacentor variabilis, Amblyomma americanum, and Ornithodorus turicata*. NIAID has funded the sequencing of the tick, *I. scapularis*, and the genome sequence is publicly available at NCBI and VectorBase (www.vectorbase.org/organisms/ixodes-scapularis).

G. National Science Foundation

The EEID program supports research on the ecological, evolutionary, and socio-ecological principles and processes that regulate the transmission dynamics of infectious diseases. The program's focus is on both the discovery, and the building and testing models that elucidate these principles and processes. Research proposals focus on understanding the determinants of transmission of diseases to humans, non-human animals, or plants; the spread of pathogens by environmental factors, vectors or abiotic agents; the population dynamics and genetics of reservoir species or alternate hosts; or the cultural, social, behavioral, and economic dimensions of disease transmission.

Research topics include zoometric, environmentally borne, vector-borne, or enteric diseases of either terrestrial, freshwater, or marine systems and organisms, including diseases of non-human animals and plants, at any scale from specific pathogens to inclusive environmental systems. Proposals for research on disease systems of public health concern to developing countries are strongly encouraged, as are disease systems of concern in agricultural and coastal marine systems. Research links to the public health research community, including participation of epidemiologists, physicians, veterinarians, food scientists, social scientists, entomologists, pathologists, virologists, and/or parasitologists.

Recently funded research projects have included:

- "Microbial Community Ecology of Tick-Borne Human Pathogens"

- "Ecological Interactions between Sudden Oak Death and Lyme Disease in California"
- "The ecology of Anaplasma phagocytophilum: Reservoirs, risk, and incidence"
- "Testing Alternative Hypotheses for Gradients in Lyme Disease in the Eastern US: Climate, Host Community and Vector Genetic Structure"
- "Investigating a rapidly emerging epidemic of babesiosis in upstate New York"

X. SUMMARY

The major TBDs of humans in the US include Lyme disease, Rocky Mountain spotted fever, ehrlichiosis, and anaplasmosis. While concentrated in specific geographic regions, they are increasing each year in both case numbers and distribution. Many of the TBDs are treatable readily with antibiotics. Some, however, can be very serious and even potentially fatal. The observed increases in numbers and distribution have most likely resulted from ecological changes that have led to greater contact between people and ticks. Integrated Pest Management (IPM) of ticks is an important line of defense against transmission of TBDs. The goal of IPM is to employ various combinations of control techniques intelligently and safely in an effort to maximize effectiveness. Multiple federal agencies of the US government perform research, surveillance, prevention, control, education, and regulation in an effort to reduce the impact of TBDs on humans. A group of agencies led by EPA and CDC have prepared this white paper in order to maximize the effectiveness of the various efforts to reduce the number of TBDs in the US. The group has established milestones for the purpose of increasing cross-agency interaction, which will increase efficiency and effectiveness, ultimately leading to a reduction in the incidence of TBDs in humans. The group also suggests the following performance measures: develop a national survey for tick abundance and distribution, develop a decision support model for cost-effectiveness of prevention, develop a habitat analysis strategy, develop a strategy for effective control of vector ticks, and establish federal research initiatives.

XI. CONCLUSIONS

Tick-borne diseases (TBDs) affect tens of thousands of Americans each year, afflicting them with serious illness that causes significant morbidity and sometimes mortality. Integrated Pest Management (IPM) of ticks that bite humans is an important part of preventing TBDs. Although better tools for vector surveillance and control would make IPM programs stronger, more effective, and less expensive, the technology already exists to start preventing TBDs. Programs exist locally for IPM of ticks, but those programs are very limited and have not prevented what appears to be the expanding importance of tick-borne diseases in the United States. Communicating the need and capability for community-wide tick IPM is a priority, as well as organizing the information and IPM techniques already available.

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XIII. WEB PAGE REFERENCES

A. CENTERS FOR DISEASE CONTROL AND PREVENTION

Tick-Borne Disease Homepage: www.cdc.gov/ticks/

Lyme disease: www.cdc.gov/lyme/

Published national guidelines on the diagnosis and management of TBDs as an MMWR: www.cdc.gov/mmwr/preview/mmwrhtml/rr5504a1.htm. An update is planned for 2012.

B. US DEPARTMENT OF AGRICULTURE

The mission areas of ARS are Nutrition, Food Safety and Quality, Natural Resources and Sustainable Agricultural Systems, Crop Production and Protection, and Animal Production and Protection (APP). Research on pests of animals and humans is conducted within APP under National Program 104, Veterinary, Medical, and Urban Entomology. National Program 104 includes 34 principle scientists at eight locations in Maryland, Florida, Mississippi, Texas, Kansas, Nebraska, and Panama (www.ars.usda.gov/research/programs/programs.htm?NP_CODE=104).

Ticks of veterinary importance are a principle target of NP104 (see action plan www.ars.usda.gov/SP2UserFiles/Program/104/NP104ACTIONPLANFY09-FY13Final.pdf). Protection of humans from ticks has been a logical by-product of veterinary efforts, especially when the tick species attack both humans and animals.

The NIFA homepage can be found at www.nifa.usda.gov

NIFA funded projects on ticks (and projects funded by USDA, ARS) can be retrieved by using the Current Research Information System CRIS. Instructions include:

- Go to the NIFA website at nifa.usda.gov/
- In the A to Z index, go to CRIS.
- 3, In CRIS, select “Assisted Search”
- In “Assisted Search” in the “Fulltext Term” field insert the word “Ticks” or another term of interest.
- Select “Search” to pull up any projects for this search term.
- For information on the full use of CRIS, use the “Help” feature

The TickApp is located at tickapp.tamu.edu/

Pest Alertn Brown Dog Tick is located at www.ncipmc.org/alerts/browndogtick.cfm

C. US Department of Defense

Annual Lyme Disease Report. www.afhsc.mil/reports?clear

Defense Medical Epidemiology Database. Users may perform queries regarding disease - including vector-borne disease rates in military populations. www.afhsc.mil/aboutDmed

D. US Environmental Protection Agency

Managing Ticks and Preventing Tick Bites
npic.orst.edu/pest/tick/index.htm

2011 Tick IPM Conference
epa.gov/pestwise/events/tick_meeting.html

Insect Repellents: Use and Effectiveness
cfpub.epa.gov/oppref/insect/index.cfm

TBD-IPM March 5-6, 2013 Conference
http://www.epa.gov/pesp/events/2013_tick_meeting.html

E. US Department of the Interior

Departmental website: DOI Safety Management Information System

www.doi.gov/safetynet/information/general/safety_program/index.html

1) US Geological Survey

USGS efforts related to vector-borne diseases are summarized on the USGS website (health.usgs.gov/vector_zoonotic), and updated in the GeoHealth Newsletter (health.usgs.gov/geohealth). Vector and vector-borne disease distributional information is available at the diseasemaps website (diseasemaps.usgs.gov)

2) National Park Service

Recent formation of the One Health Group website advocates that the health of people, animals, and the environment are inextricably interconnected and should be approached as one www.onehealthcommission.org.

11-Step Process to Developing and Implementing an Integrated Pest Management Strategy www.nature.nps.gov/biology/ipm/

Guide for National Park Service Employee:
www.**nps**.gov/public_health/info/eh/.../**NPS**_RP_Manual_v2.pdf

F. National Institute s of Health

Resources at NIH relating to tick-borne diseases:

- NIH RePORTER
- NIAID Vector Biology Program
- NIAID Tick -borne Diseases
- NIAID Lyme Disease Research Program

Other sources of information grants issued by National Institutes of Health are as follows:

report.nih.gov/ and projectreporter.nih.gov/reporter.cfm

XIV. AGENCY CONTACTS

CENTERS FOR DISEASE CONTROL AND PREVENTION

National Center for Emerging and Zoonotic Infectious Diseases, Division of Vectorborne Diseases, Bacterial Diseases Branch

Lyme disease, tularemia, and tick-borne relapsing fever surveillance, prevention, and control
C. Ben Beard, CBeard@cdc.gov, 970.221.6418

National Center for Emerging and Zoonotic Infectious Diseases, Division of Vectorborne Diseases, Rickettsial Zoonoses Branch

Rickettsioses, anaplasmosis, and ehrlichiosis surveillance, prevention, and control
Robert Massung, RMassung@cdc.gov, 404.639.1082
William Nicholson, WNicholson@cdc.gov, 404.639.1095

National Center for Environmental Health, Division of Emergency and Environmental Health Services, Environmental Health Services Branch

Capacity building, workforce development, and technical assistance to contribute to vector control and IPM for ticks
Michael Herring, MHerring@cdc.gov, 770.488.7351
Justin Gerding, JGerding@cdc.gov, 770.488.3972

National Institute for Occupational Safety and Health, Education and Information Division, Document Development Branch

Prevention of occupational exposure to TBDs
Kathleen MacMahon, KMacMahon@cdc.gov, 513.533.8547
Brenda Jacklitsch, BJacklitsch@cdc.gov, 513.533.8369

US DEPARTMENT OF AGRICULTURE

Agricultural Research Service, chief scientific in-house research arm (www.ars.usda.gov)
Daniel Strickman, Daniel.Strickman@ars.usda.gov, 301.504.5771

Animal and Plant Inspection Service,
Angela James, mailto:Angela.M.James@aphis.usda.gov, 970.494.7278

National Institute Food and Agriculture, www.nifa.usda
Herbert Bolton, HBolton@nifa.usda.gov, 202.401.4201

US DEPARTMENT OF DEFENSE

US Army Public Health Command, Entomological Sciences Program

Ellen Stromdahl, ellen.stromdahl@us.army.mil, 410.436.3613
phc.amedd.army.mil/topics/envirohealth/epm/Pages/

Armed Forces Pest Management Board (www.afpmb.org)

Contact: Harold.harlan@osd.mil

Walter Reed Biosystematics Unit
www.wrbu.org/ www.tickmap.org

Armed Forces Health Surveillance Center
www.afhsc.mil, Medical Surveillance Monthly Report: "www.afhsc.mil/msmr"

Naval Medical Research Center, Dr. William Miller, Army Environmental Command, Ft. Sam Houston, TX 78234-7664 "William.b.miller54@mail.mil", 210. 466.1767,
Viral and Rickettsial Disease Dept.: " www.med.navy.mil/sites/nmrc/Pages/id_rd.html

US ENVIRONMENTAL PROTECTION AGENCY

Office of Pesticide Programs

Tick IPM and Environmental Stewardship
Candace Brassard, brassard.candace@epa.gov, 703.305.6598

Biochemical Pesticides
Clara Fuentes, fuentes.clara@epa.gov, 703.308.8017

Biological and Economic Analysis
David Brassard, brassard.david@epa.gov, 703.308.8104

Habitat Protection, Invasive Species
Russell Jones, jones.russell@epa.gov, 703.308.5071

Integrated Pest Management in Schools
Thomas Cook, cook.thomas@epa.gov, 214.665.9731

Sherry Glick, glick.sherry@epa.gov, 214.665.6713

Office of Air and Radiation, Office of Atmospheric Programs, Climate Change
Lesley Jantarasami, jantarasami.lesley@epa.gov, 202.343.9929

Office of Research and Development, Ecosystems, Biodiversity and Disease Transmission
Montira Pongsiri, pongsiri.montira@epa.gov, 202.564.0978

EPA Region 1 (New England)
Robert Koethe, koethe.robert@epa.gov, 617.918.1535
Greg Hellyer, hellyer.greg@epa.gov

US GEOLOGICAL SURVEY

Scientific research arm of the Department of the Interior:

Program Coordinator; Energy, Minerals & Environmental Health
Patricia Bright, pbright@usgs.gov, 703.648.4058

Patuxent Wildlife Research Center

Howard Ginsberg, University of Rhode Island, hginsberg@usgs.gov, 401.874.4537

National Wildlife Health Center

Christopher Brand, cbrand@usgs.gov, 608 270-2440

NATIONAL INSTITUTES OF HEALTH

National Institute of Allergy and Infectious Diseases (NIAID)

Supports intramural and extramural research related to TBDs of humans.

Adriana Costero, Vector Biology Program Officer, acostero@niaid.nih.gov, 301.435.2854

Joseph Breen, Lyme Disease Program Officer, jbreen@niaid.nih.gov, 301.435.2855

Sam Perdue, Rickettsial and Related Diseases Program Officer, sperdue@niaid.nih.gov, 301.402.5083

Patricia Repik, Arboviruses Program Officer, prepik@niaid.nih.gov, 301.496.7453

National Institute of Arthritis and Musculoskeletal and Skin Diseases (NIAMS)

Focuses on research into the causes, treatment, and prevention of arthritis, musculoskeletal, and skin diseases, including Lyme arthritis

www.niams.nih.gov/

The National Institute of Neurological Disorders and Stroke (NINDS)

Supports research to reduce the burden of neurological disease, including neurological Lyme disease;

www.ninds.nih.gov/

The National Institute of General Medical Sciences (NIGMS)

Supports basic research to better understand life processes and lay the foundation for advances in disease diagnosis, treatment, and prevention.
www.nigms.nih.gov/

The National Human Genome Research Institute (NHGRI)

In collaboration with NIAID, NHGRI supports the sequencing of infectious disease pathogens as well as invertebrate vectors of disease.

www.genome.gov/;
www.niaid.nih.gov/labsandresources/resources/dmid/Pages/default.aspx

NATIONAL PARK SERVICE

Office of Public Health, Epidemiology Branch
David Wong, David_wong@nps.gov, 505.248.7806

Integrated Pest Management Program
Carol DiSalvo, Carol_disalvo@nps.gov, 202.513.7183

Wildlife Health Branch: Kevin Castle, Kevin_castle@nps.gov, 970.267.0104

Office of Risk Management: Michael M. Quinn, Michael_M_Quinn@nps.gov, 202.513.7214

NATIONAL SCIENCE FOUNDATION

Ecology and Evolution of Infectious Diseases: Sam Scheiner, sscheine@nsf.gov