Action Plan: National Program 104 – Veterinary, Medical, and Urban Entomology (September 2014 – September 2019)

Goal: The mission of National Program 104 (NP 104), Veterinary, Medical, and Urban Entomology, is to improve human and food-animal well-being through development of effective and safe pest control methods. The emphasis of the program is on agriculture, with the goal of reducing the 12% loss experienced by American livestock production caused by insects and ticks. Research with agricultural benefit has implications for human health, both directly by reducing the risk of zoonotic diseases, and indirectly by developing methods that can be used to combat vectors of human pathogens. The USDA has contributed to the study of insects and ticks that transmit human pathogens since the late 1800s. Theobald Smith's discovery of *Babesia* transmission by cattle fever ticks influenced the medical world of the day, looking at arthropods as vectors of malaria parasites, yellow fever virus, and plague bacteria. USDA scientists wrote the first review of the mosquitoes of the western hemisphere, completing the work in 1912. Work at USDA's Orlando Laboratory beginning in 1942 is credited with the products that broke the back of the traditional war-time diseases: malaria, plague, and epidemic typhus. Work on medically important arthropods and their control has continued, most prominently during the last decade sponsored by the Department of Defense under the Deployed War-Fighter Protection Program.

Background:

Integrated Pest Management

To achieve its goals, research within NP 104 uses a framework of components within the idealized structure of applied entomology known as Integrated Pest Management (IPM), which provides the basic organization for the program's research. Developed during the 1960s and 1970s, IPM drew on the previous hundred years of accumulated entomological wisdom to produce a methodology that would guide research, education, and application toward solutions that were effective, economical, sustainable, and safe. IPM can be divided into four elements: *risk assessment and biology, surveillance, control,* and *monitoring and sustainability*. These are listed in the order in which they would be applied operationally, i.e., determining the problem, assessing the problem, solving the problem, and maintaining that solution. From the standpoint of research, the order could be quite different and require studies on surveillance and control in order to understand the economic thresholds implied by risk assessment.

Risk Assessment and Biology

Risk assessment and biological study are the first necessary steps for any IPM program. Background information on the identification (systematics and taxonomy), distribution (spatial and temporal), behavior (particularly potential for causing damage), and bionomics 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.

Surveillance

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 occurrence of infection. Surveillance also includes measurement of correlates such as soil moisture or canopy density that are related to pest population. In addition, trap development and interpretation of trapping results are important aspects of research on surveillance.

Control

Control includes all measures that might be taken to prevent damage from a pest. Common classifications of techniques include cultural control, physical control (source reduction and mechanical control), biological control, and chemical control using synthetics or bio-rational compounds (e.g., botanical compounds, double-stranded RNA, etc.). In practice, each method is applied individually and locally, so that projection of research results from the laboratory to an integrated program on the farm is especially challenging. Development of new methods often requires coordination with industry and extension to translate results into action. The other major developmental challenge is the consideration of biology in order to integrate control methods efficiently. Careful timing of each kind of treatment 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.

Monitoring and Sustainability

Monitoring a pest to ensure continuous, successful IPM has proven very difficult for the field of entomology. Farmers or other applicators may lose interest in the problem once it has disappeared. 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 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 surveillance will be the same as those for monitoring, but the deployment of those tools will be different. One way to think of how to maintain success is to view sustainability as the result of accurate risk assessment and monitoring. Once monitoring shows that pest activity is below a threshold determined by risk assessment, then IPM activity could pause.

All of the research and development in NP 104 supports one of the four elements of IPM. Fundamental research, even that which aims to discover the unknown, can eventually lead to advances in IPM; in fact, such work is the only way to find truly new solutions to agricultural problems. Applied research is more closely related to the actual application of IPM.

Climate Change

One of the greatest challenges facing agriculture in the United States and worldwide is the prospect of major changes in the proportions of gases in the atmosphere leading to direct physiological effects on organisms and to changes in long-term weather patterns (http://www.usda.gov/oce/climate_change/effects.htm). Whether through direct climate effects or indirect botanical effects, these changes will have a great influence on the arthropods that concern us in NP 104. Some of those effects might be subtle, like changes in the day length required to induce diapause. Other effects will be more obvious changes in distribution, including expansion of the distributions of some species from warmer or drier regions and expansion of the distribution of species that are currently limited by low temperatures. The subsequent interactions between the many species that make up a particular ecosystem could be complicated and result in local adaptations by individual species or populations, with potentially negative effects on agriculture.

Probably the most likely outcome from climate change is redistribution of species. This will be complicated by the accelerating trend in establishment of damaging invasive species globally, usually attributed to much greater volumes of transport. As ecosystems experience disruption from climate-induced redistribution of species and by introduction of invasive species, we may see larger areas transformed into disturbed habitats that are ever more susceptible to the establishment of those species.

Understanding the general and specific risks from these processes could help prevent the worst consequences. Producers could adjust their practices to overcome new threats, breeders could work on more resistant genetic types, and entomologists could tailor integrated pest management programs.

NP 104 can contribute to this field in a number of ways. A list of publications that are examples of studies that addressed the challenges of climate change and vector species, providing a preliminary view of the state of the science, can be found on the NP 104 website along with this action plan. Generally, the first studies to be undertaken by NP 104 might include:

1. *Application of existing models to NP 104 target pests.* New techniques to analyze distribution with respect to climate factors and to predict how climate change could influence distribution have been developed during the last decade. Application of those techniques to key pests and to potentially invasive medical and veterinary vectors species would help to prepare the United States for a likely threat to its agriculture and health. Such studies should be feasible given current personnel and funding, requiring only that the parameters of the pests of interest to NP 104 be used in existing models. Although those results would not be tested in reality for decades, the estimates would form hypotheses that could be evaluated.

2. *Studies of NP 104 target pests that contribute to understanding how they could be affected by climate change.* Another possible approach within current capabilities would be to identify important gaps in our knowledge of biology and ecology to adapt existing models to the purposes of NP 104. An example of such a study would be determination of critical temperatures for development of a key vector species.

3. *Examination of cross-cutting research within NP 104 from the perspective of climate change.* Webinars involving key scientists in NP 104 and cooperating laboratories would be a medium for identifying relevant lines of research that might be combined to answer significant problems related to climate change. For example, metagonomics of bacteria in flies might have great relevance to the response of these pests to climate change.

Relationship of This National Program to the USDA Strategic Plan:

This action plan is relevant to two objectives in the USDA Strategic Plan for 2010-2015 (http://www.ocfo.usda.gov/usdasp/sp2010/sp2010.pdf).

The first is within Strategic Goal 2 to ensure national forests and private working lands are conserved, restored, and made more resilient to climate change while enhancing our water resources. Objective 2.2 (lead efforts to mitigate and adapt to climate change) is a major thrust of the NP 104 Action Plan.

The second is in Strategic Goal 3 to help America promote agricultural production and biotechnology exports as America works to increase food security. Objective 3.1 (ensure U.S. agricultural resources contribute to enhanced global food security) is addressed in this action plan because successful completion of NP 104 research will increase the efficiency of food animal production.

Relationship of This National Program to the USDA REE Action Plan:

This Action Plan fits under the more general guidance of the USDA REE Action Plan's (http://www.ree.usda.gov/ree/news/USDA_REE_Action_Plan_02-2012_2.pdf) Goal 1: Local and global food supply and security, Subgoal 1B: Crop and animal health. It also addresses Goal 2: Responding to climate and energy needs, Subgoal 2A: Responding to climate variability.

Relationship of This National Program to the ARS Strategic Plan:

This Action Plan addresses the high level goals and objectives of the 2012-2017 Strategic Plan: (http://www.ars.usda.gov/SP2UserFiles/Place/00000000/NPS/OAA/ARS%20Strat%20Plan%202012%20-%202017%20Final.pdf) as part of ARS Strategic Goal Area 4: Animal Production and Protection. Within that Strategic Goal Area, Goal 4.2 (Prevent and control pests and animal diseases that pose a threat to agriculture, public health, and the well-being of American citizens) includes the purposes of NP 104. One performance measure sets the targets for NP 104 research within the USDA ARS Strategic Plan:

Performance Measure 4.2.1: Provide scientific information to protect animals, humans, and property from the negative effects of pests and infectious diseases. Develop and transfer tools to the agricultural community, commercial partners, and government agencies to control or eradicate domestic and exotic diseases and pests that affect animal and human health.

Targets:

4.2.A: Provide scientific information to protect animals, humans, and property from the negative effects of pests and infectious diseases.

4.2.B: Develop and transfer tools to the agricultural community, commercial partners, and government agencies to control or eradicate domestic and exotic diseases and pests that affect animal and human health.

Research Component Overview:

The NP 104 Action Plan contains general strategies and specific actions within the following organizational hierarchy:

1) Components, which are general categories of agriculturally useful research areas identified with the help of stakeholders (see the summary of 2013 stakeholder input in the "Workshops" section of the ARS website at http://www.ars.usda.gov/research/programs/programs.htm?np_code=104&docid=23419)

2) Problem Statements, indicating the specific nature and scope of problems to be solved by ARS.

3) Research Needs, which are the kinds of research to be performed by ARS in order to achieve a successful resolution of the problem.

The components of the program have been modified in order to reflect the completion of termite research and to attempt to clarify the organization of the program. The components of the program are:

Component 1: Medical entomology for the public and the military.
Component 2: Veterinary entomology
Component 3: Ants

Component 1: Medical Entomology for the Public and the Military

USDA has long supported public health by applying agricultural expertise in insect control to arthropods that transmit human pathogens. The research aims to solve problems and make substantial improvements in methods by performing innovative basic research, inventing new ways to detect and control vectors, and by developing products and strategies.

Problems in medical entomology could be categorized in a number of ways, for example, by product, by disease, or by taxon of arthropod vector. We have chosen to use taxa because the expertise of medical entomologists, particularly in training institutions, has tended to focus this way. NP 104 and its antecedents in USDA have worked on a wide variety of vector groups during the last 12 decades. Currently, the emphasis is on those groups with greatest disease importance and those that have the greatest crossover significance to food animal health.

Public and military interests were separated in the last action plan. The two components were combined in this action plan because the ultimate goal of disease prevention is the same for both the military and the civilian public. Both public and military medical entomology place great emphasis on product development, with the greatest difference probably being the emphasis on domestic problems by the former and foreign problems by the latter. The military has its own medical entomology research program that includes efforts both in the United States and overseas. ARS laboratories have often worked with military ones.

Problem Statement 1A: Mosquitoes
Worldwide, mosquitoes are the insects that threaten human health most severely. The most important diseases caused by mosquito-borne pathogens are malaria, dengue, Japanese encephalitis, and yellow fever. There are about 3,400 species of mosquitoes described, but only two or three hundred are important to human health. Many species rarely bite humans and some never bite at all. Most study of mosquitoes tends to get concentrated on the important vectors and the species that are easiest to manipulate in the laboratory, even though other species may also transmit pathogens, serve as enzootic vectors, or cause severe annoyance problems.

The previous action plan emphasized work on *Aedes albopictus*, the Asian tiger mosquito. Progress against this species achieved during the Areawide Integrated Pest Management Project revealed a number of weaknesses in our ability to control this species. The Asian tiger mosquito is particularly difficult to control, threatens to expand its range in the United States even further, and at worst could be the cause of severe epidemics of chikungunya virus.

Anopheles mosquitoes transmit the parasites that cause malaria. The United States had severe problems with malaria through the 1920s and it is still a principle cause of morbidity and mortality throughout the tropics and in parts of temperate Asia. The importance of malaria prevention is increasing as the military shifts emphasis to Africa and eastern Asia. In addition, there is a threat of invasive *Anopheles* species that could increase the likelihood of malaria epidemics, as happened when *Anopheles arabiensis* invaded Brazil in the 1930s and Egypt in the 1940s.

Other genera of mosquitoes also include important species. *Aedes aegypti* remains the principle vector of dengue virus worldwide. Many of the lessons learned on *Aedes albopictus* control apply to *Aedes aegypti. Culex tarsalis* is a major vector of viral encephalitides in the western United States and *Culex pipiens/quinquefasciatus* is an important vector throughout the United States and worldwide. A number of floodwater *Aedes* and *Psorophora* species, including *Aedes vexans* and *Psorophora columbiae*, are severe pests and occasional viral vectors. The threat of new invasive species is particularly severe for mosquitoes that develop in containers, like *Aedes notoscriptus* from Australia, or that transmit a particular virus, like *Culex tritaeniorhynchus* as a vector of Japanese encephalitis virus.

Research Needs:

1. Evaluation of the risk and economic impact of mosquito-borne pathogens during the next three decades, both domestically and in potential foreign military theaters, considering both human and animal diseases, as well as native, invasive, and potentially invasive vector species. Specifically, the kinds of risk include introduction and establishment of invasive species, range expansion of invasive or native species, and increases in disease incidence.

2. Development of new and adaptation of existing active ingredients (toxicants, synergists, and formulations) for mosquito control including adulticides, textile treatments (bed nets, curtains, clothing) and larvicides that overcome current limitations on use.

3. Improvement of surveillance techniques resulting in a standardized vector detection and surveillance system that is effective for all important groups of mosquitoes and that provides rapid detection of vector species and pathogens.

4. Development of personal protection systems including new topical repellents that use a lower percentage of active ingredients; spatial repellents that protect a room, a group of people, or an individual from point sources; and textile treatments that are alternatives to current pyrethroid impregnation.

5. Development and evaluation of devices, techniques, insecticides, or spatial repellents that prevent mosquitoes from being transported on vehicles, aircraft, or ships.

6. Determination of the effects of pathogens in mosquitoes on susceptibility to control and personal protection techniques with emphasis on malaria parasites and dengue virus.

7. Coordination with military assets to evaluate effectiveness and use of ARS-invented technology under deployment conditions.

Anticipated Products:

Improved risk assessment	***Improved surveillance***	***Improved control***	***Improved sustainability and control***
✓	✓	✓	✓

Impact: Earlier detection of invasive species, more effective IPM of vectors and pest mosquitoes

Problem 1A Resources:

The following locations have research projects addressing the problem statement identified under Problem 1A:

- Mosquito and Fly Research Unit, Center for Medical Agricultural and Veterinary Entomology, Gainesville, FL
- Invasive Insect Biocontrol and Behavior Laboratory, Beltsville, MD
- Biological Control of Pests Research Unit, National Biological Control Center, Stoneville, MS

Problem Statement 1B: Flies

So-called “filth flies” in the families Muscidae, Calliphoridae, and Sarcophagidae transmit food-borne pathogens like *Escherichia coli, Salmonella enteriditis,* and noroviruses. Recent work has shown that house flies (*Musca domestica*), at least, amplify some pathogens in their guts. As a result, flies can be a major cause of diarrheal disease in humans. Little information exists on how pathogenic bacteria multiply within and on house flies, knowledge of which would greatly improve our ability to limit their role as vectors of those pathogens. The military sees diarrheal disease as its third most important infectious disease threat and routinely treats flies to protect deployed personnel. Unfortunately, the state of the art for fly control is much less effective than for mosquitoes. The best strategy to separate flies from humans is uncertain, though dozens of different kinds of products are used in specific situations. Among the gaps in these techniques are effective larval control, interruption of fly movement from larval sources to humans, and insecticide resistance management.

Research Needs:

1. Quantification of the distribution, health threat, and associated costs of flies with respect to various populations (e.g., urban, agricultural, military) and projected three decades into the future, accounting for climate change.

2. Quantitative evaluation of gaps in techniques available for integrated fly control, especially in a military setting and including establishment of realistic action thresholds.

3. Development of more effective larval control techniques.

4. Physiological and other research that supports development of effective resistance management.

5. Bioinformatic study of the recently sequenced house fly genome, supporting research needs described above.

Anticipated Products:

Improved risk assessment	*Improved surveillance*	*Improved control*	*Improved sustainability and monitoring*
✓		✓	

Impact: Reduced prevalence of food-borne diseases

Problem 1B Resources :

The following locations have research projects addressing the problem statement identified under Problem 1B:

- Mosquito and Fly Research Unit, Center for Medical Agricultural and Veterinary Entomology, Gainesville, FL
- Agroecosystem Management Research Unit, Lincoln, NE
- Arthropod Borne Animal Diseases Research Unit, Manhattan, KS

Problem Statement 1C: Sand flies
Phlebotomine sand flies are a subfamily of Psychodidae that include the familiar and non-biting drain flies. Sand flies transmit three kinds of pathogens causing leishmaniasis, bartonellosis, and sand fly fever. Sand fly fever has been a major problem in particular regions for the military, but most recently leishmaniasis was a major problem in Iraq and a threat in Afghanistan. Typical control techniques like fogging and residual treatments were only sometimes effective. Leishmaniasis also occurs in Africa and the Western Hemisphere, though it is a very rare disease in the United States. From the standpoint of NP 104, sand flies are mainly a military problem overseas.

Research Needs:

1. Develop and evaluate attractant based surveillance devices for sand flies that provide a practical alternative to carbon dioxide-baited traps.

2. Screen personal protection products (e.g., topical repellents, spatial repellents, treated bed nets) against sand flies.

3. Screen toxicants and formulations developed for mosquito control against sand flies and assemble techniques into integrated management programs that reduce the risk of disease.

Anticipated Products:

Improved risk assessment	*Improved surveillance*	*Improved control*	*Improved sustainability and monitoring*
	✓	✓	

Impact: Fewer cases of leishmaniasis and sand fly fever in the military

Problem 1C Resources:

The following location has research projects addressing the problem statement identified under Problem 1C:

- Knipling-Bushland U.S. Livestock Insects Research Laboratory, Kerrville, TX
- Mosquito and Fly Research Unit, Center for Medical Agricultural and Veterinary Entomology, Gainesville, FL
- Invasive Insect Biocontrol and Behavior Laboratory, Beltsville, MD

Problem Statement 1D: Ticks

Ticks transmit a wide variety of pathogens, many of which are associated with potentially fatal disease. Fortunately, most of the diseases are relatively uncommon in the United States, including human babesiosis, Rocky Mountain spotted fever, ehrlichiosis, anaplasmosis, and Colorado tick fever. The big exception is Lyme disease caused by bacteria and transmitted by *Ixodes pacificus* on the West Coast and *Ixodes scapularis* in much of the rest of the United States. That disease affects at least 20,000 people per year concentrated in the Northeast and the northern Midwest. The public health and medical research communities are actively engaged with the clinical aspects of Lyme disease, but vector control and bite prevention are areas in which NP 104 has particular expertise. It is necessary to focus the program to the area in which NP 104 can make the greatest contribution rather than to address the full spectrum of problems. Those problems include the challenge of preventing disease by personal protection when a high percentage of the bites are infected, evaluation of the causes of the rapid expansion of the vector's range and Lyme disease, and risk assessment of the threat of importation of other vectors from Europe and Asia. The problem on which USDA ARS has chosen to concentrate is community control of the vectors.

Research Needs:

1. Develop and evaluate new techniques for control of *Ixodes pacificus* and *Ixodes scapularis;* and assemble available techniques into designs for integrated community control programs.

2. Test anti-tick vaccines for potential use in deer against *Ixodes*.

Anticipated Products:

Improved risk assessment	*Improved surveillance*	*Improved control*	*Improved sustainability and monitoring*
	✓	✓	

Impact: Fewer cases of Lyme disease in the United States

Problem 1D Resources :

The following locations have research projects addressing the problem statement identified under Problem 1D:

- Invasive Insect Biocontrol and Behavior Laboratory, Beltsville, MD
- Knipling-Bushland U.S. Livestock Insects Research Laboratory, Kerrville, TX

Problem Statement 1E: Bed bugs

Bed bugs remain a severe problem for the hospitality industry, housing shelters, public housing, and other multi-family housing arrangements. The last five years have seen introduction of new commercial products for bed bug treatment and a better understanding of the chemical ecology of these insects. New volatile toxicants developed by ARS may prove to be particularly useful against bed bugs. Chemical signaling compounds could be the basis for accurate surveillance devices and effective baits.

Research Needs:

1. Determine signaling compounds that affect key events in the life history of bed bugs.

2. Develop new surveillance and control techniques for bed bugs.

Anticipated Products:

Improved risk assessment	*Improved surveillance*	*Improved control*	*Improved sustainability and monitoring*
	✓	✓	

Impact: Fewer premises infested with bed bugs

<u>Problem 1E Resources :</u>

The following location has research projects addressing the problem statement identified under Problem 1E:

- Invasive Insect Biocontrol and Behavior Laboratory, Beltsville, MD

Component 2: Veterinary Entomology

For NP 104, veterinary entomology is the study of how arthropods affect animal agricultural production and how to reduce negative economic impacts. In some ways, this is a much broader field than medical entomology because more species need to be protected, resulting in a greater variety of arthropods and vector-borne pathogens. Although welfare of animals is important, the problems of veterinary entomology are basically economic. As a result, arthropod-related challenges of veterinary entomology are usually more tolerated than similar problems in medical entomology. Another contrast between the two fields is that animals are used for food; therefore, chemical residues in tissue are of much greater concern than in humans. Finally, animals are much more exposed to arthropods than humans in most situations in the United States. Animals are more likely to get arthropod-borne infections and to suffer direct damage from bites and infestations. Thanks to the efforts of American entomologists, a number of formerly key animal pests have been reduced to the status of unusual problems (cattle lice, sheep mange mites, cattle bot flies) or pushed completely out of the United States (cattle fever ticks, screwworm flies). Those successes can require scientific maintenance as conditions change and many vectors remain under-controlled.

Problem Statement 2A: Invasive ticks

The greatest threat from ticks to U.S. agriculture is presented by cattle fever ticks, *Rhipicephalus (Boophilus) annulatus* and *Rhipicephalus (Boophilus) microplus*. These ticks transmit two species of *Babesia* to cattle that puts a strain on the economics of cattle production. These species used to occur throughout the southern United States but were eradicated between 1907 and 1943 by systematically dipping cattle and quarantining pastures. Since then, APHIS and the Texas Animal Health Commission maintain a quarantine zone in southeastern Texas where Mexican cattle could accidentally wander across the border with their ticks. This system continues to keep cattle fever ticks out of the United States, but is constantly challenged by the expense of dipping infested cattle, quarantining pastures, and by moving ticks on much-expanded populations of native white-tailed deer and exotic ungulates (e.g., nilgai). NP 104 has made progress toward overcoming these challenges and needs to continue those efforts. It would also be prudent for NP 104 to consider the risk from other potentially invasive tick vectors (e.g., *Hyalomma* spp., *Rhipicephalus appendiculatus*) and species that might expand their ranges within the United States (e.g., *Amblyomma americanum, Amblyomma maculatum, Amblyomma cajenense*).

<u>Research Needs</u>:

1. Determine the risk of range expansion and introduction of potentially invasive ticks to the United States with projection for three decades in response to estimates of climate change.

2. Determine the impact of invasive weeds on cattle fever ticks, particularly the egg and larval habitat.

3. Continue evaluation and product development of new methods for controlling cattle fever ticks, including biological control, vaccines, deer treatment, long-lasting cattle treatment, etc.

4. Develop new tools for surveillance, detection, and monitoring in order to evaluate action thresholds and treatment options for cattle fever ticks and other invasive ticks, basing thresholds on potential economic impact.

5. Evaluate the potential for feral swine to host ticks that transmit foreign animal diseases.

<u>Anticipated Products</u>:

Improved risk assessment	***Improved surveillance***	***Improved control***	***Improved sustainability and monitoring***
✓	✓	✓	✓

<u>Impact</u>: Lower costs for cattle producers in southern Texas; more effective exclusion of cattle fever tick from the United States; more efficient control of cattle fever tick in infested areas; greater food security in the tropics

<u>Problem 2A Resources:</u>

The following location has research projects addressing the problem statement identified under Problem 2A:

- Knipling-Bushland U.S. Livestock Insects Research Laboratory, Kerrville, TX

Problem Statement 2B: Stable flies
Stable fly bites have direct impact on cattle, reducing weight gain of animals due to annoyance from the flies. Although stable flies have been in the United States for centuries, they are an invasive species in the sense that they probably originated from Africa and came to the New World via Europe. In Africa, the genus (*Stomoxys*) includes over ten species, at least four of which are

pests of cattle. The risk of introduction of new species of *Stomoxys* to the United States is unknown. Controlling this kind of fly has been challenging because the larvae can develop in a range of habitats consisting of decaying vegetation, decaying vegetation in soil, and in soil mixed with animal urine and feces. The adults can fly long distances under certain conditions, supporting the hypothesis that a large proportion of the population migrates north with the season in spring. Control techniques include ear tags, topical applications to animals, residual insecticides, and traps. Larval control has been limited to sanitation where possible (e.g., compost heaps) and recent development by ARS of cyromazine treatment of the soil near round-bail cattle feeders.

<u>Research Needs</u>

1. Estimate changes in the timing of stable fly outbreaks due to climate change during the next three decades.

2. Estimate the risk of introduction of additional species of *Stomoxys*.

3. Examine the biology of stable flies, including larvae, in order to find new strategies for control.

4. Develop new methods for adult control and bite prevention based on attractants and repellents.

<u>Anticipated Products</u>:

Improved risk assessment	***Improved surveillance***	***Improved control***	***Improved sustainability and monitoring***
			

<u>Impact</u>: Better efficiency of animal production and less negative effects from flies for people nearby

<u>Problem 2B Resources:</u>

The following locations have research projects addressing the problem statement identified under Problem 2B:

- Mosquito and Fly Research Unit, Center for Medical Agricultural and Veterinary Entomology, Gainesville, FL
- Knipling-Bushland U.S. Livestock Insects Research Laboratory, Kerrville, TX
- Agroecosystem Management Research Unit, Lincoln, NE

Problem Statement 2C: House flies

House flies are a medical problem in that they transmit human pathogens, but they also negatively affect livestock. Specifically, infections causing mastitis, pink eye, and other illnesses have been attributed to bacterial transmission from house flies. Since flies sometimes travel great distances from larval sources, agricultural operations that produce them are often blamed for flies affecting humans. Sanitation is usually a part of fly control but farming operations often cannot remove the many larval sources associated with animal waste, spilled feed, etc. Traps, residual insecticides, attractive baits, and biological control are all helpful. Larval control remains largely experimental because the maggots reside below the surface of media.

Research Needs:

1. Evaluate the projected effectiveness of biological control throughout the United States during the next three decades in response to predicted climate change.

2. Develop methods for larval control based on larval biology.

3. Assess the risk of bacterial transmission by studying the interactions of flies and bacteria.

4. Continue development of new methods to control adult flies with emphasis on resistance management.

5. Evaluate the economic impact of flies on agriculture.

Anticipated Products:

Improved risk assessment	***Improved surveillance***	***Improved control***	***Improved sustainability and monitoring***
✓		✓	✓

Impact: Better efficiency of animal production and less negative effect from flies for people nearby

Problem 2C Resources:

The following locations have research projects addressing the problem statement identified under Problem 2C:

- Mosquito and Fly Research Unit, Center for Medical Agricultural and Veterinary Entomology, Gainesville, FL
- Arthropod Borne Animal Diseases Research Unit, Manhattan, KS

- Agroecosystem Management Research Unit, Lincoln, NE

Problem Statement 2D: Horn flies
Horn flies, like stable flies, have been in the Western Hemisphere for hundreds of years. Despite direct treatment of livestock and use of feed-through growth regulators, horn flies remain a major problem for producers in the United States and southern South America. Horn fly adults tend to stick very close to cattle, quickly ovipositing in feces and then returning to the cow. These habits may make this species particularly susceptible to genetic control and the sterile insect technique. Successful replication of these techniques could reduce pesticide use and make a major improvement in the economy of cattle production.

Research Needs:

1. Evaluate the economic impact of horn flies in the United States.

2. Estimate the feasibility of genetic and sterile-insect control of horn flies based on completion of the horn fly genome.

3. Develop genetic and/or sterile-insect based control methods for horn flies.

4. Assess the risk of bacterial transmission by studying the interactions of flies and bacteria.

Anticipated Products:

Improved risk assessment	***Improved surveillance***	***Improved control***	***Improved sustainability and monitoring***
✓		✓	

Impact: Decrease impact of horn flies on cattle production

Problem 2D Resources:

The following location has research projects addressing the problem statement identified under Problem 2D:

- Knipling-Bushland U.S. Livestock Insects Research Laboratory, Kerrville, TX

Problem Statement 2E: Screwworm flies
The New World screwworm fly (*Cochliomyia hominivorax*) was eradicated from the southern United States, Mexico, and all of Central America by systematic application of the sterile-insect technique. Currently, the U.S. government (USDA APHIS) funds 90% and the Panamanian

government funds 10% of a binational commission responsible for the production and distribution of millions of radiation-sterilized screwworm flies in eastern Panama. This activity forms a barrier that prevents reentry of the damaging species into Central and North America. One of the most successful entomological programs of all time, this operation continues to require technical support from ARS in order to adjust to new problems and to reduce costs.

Research Needs:

1. Completion of the development of a transgenic male-only strain that will reduce the cost of production and increase the effectiveness of each fly released.

2. Development of screwworm attractants and oviposition stimulants to be used in baits and to help synchronize rearing procedures.

3. Determination of precise nutritional requirements of screwworm flies and assemble alternative diets that allow rearing operations to take advantage of lower cost ingredients.

4. Continuation of modeling screwworm habitats in order to develop more precisely targeted release methods.

5. Examination of micro-environments in the screwworm production plant in order to make rearing procedures more efficient.

6. Development of methods to identify the sources of screwworm based on genetic characteristics.

Anticipated Products:

Improved risk assessment	***Improved surveillance***	***Improved control***	***Improved sustainability and monitoring***
	✓	✓	✓

Impact: Decrease costs of the Screwworm Eradication Program

Problem 2E Resources:

The following location has research projects addressing the problem statement identified under Problem 2E:

- Screwworm Research Unit, Pacora, Panama

Problem Statement 2F: Mosquitoes
Livestock and poultry are heavily exposed to mosquitoes but, with few exceptions, there is little understanding of their current impact. The potential for introduction of damaging invasive species is particularly broad because of the variety of pathogens and vectors. Of particular concern are Rift Valley fever and Japanese encephalitis, viruses transmitted by many species. *Aedes vexans* and *Culex tarsalis* are two important veterinary species that also affect humans. NP 104 has successfully determined the population genetic structure of these two species by examining the full genomes of dozens of populations throughout the country. The next step in understanding the significance of the population structure is to examine the biological properties of the subpopulations, especially vectorial capacity and host preference. These steps are necessary to determine the regional importance of these species to animal production.

Research Needs:

1. Use ecological niche modeling to determine the characteristics of the ranges of subpopulations of *Aedes vexans* and *Culex tarsalis,* projecting those distributions three decades into the future according to climate change models.

2. Determine biological characteristics of subpopulations of *Aedes vexans* and *Culex tarsalis* that are likely related to damage to animal production.

Anticipated Products:

Improved risk assessment	***Improved surveillance***	***Improved control***	***Improved sustainability and monitoring***
✓			

Impact: Determination of where and when it is important to control *Aedes vexans* and *Culex tarsalis* to protect food animals

Problem 2F Resources:
The following location has research projects addressing the problem statement identified under Problem 2F:

- Arthropod Borne Animal Diseases Research Unit, Manhattan, KS

Problem Statement 2G: Biting midges
Severe outbreaks of bluetongue virus in Europe, epizootic hemorrhagic disease in the United States, and the emergence of Schmallenberg virus have reemphasized the need to examine the characteristics of these vectors. Relatively little is known about the larval ecology of these insects, making larval control problematic. Biological interaction between pathogens and vectors are also

poorly understood, detailed work on the “secretome” (proteins in the saliva) offers new directions to examine the problem. Interaction between the bacterial flora of the midges and viral pathogens could also be important and lead to completely novel methods of intervention.

Research Needs:

1. Use ecological niche modeling to estimate the ranges of important species and project distribution for three decades into the future according to climate change scenarios.

2. Determine behaviors and distribution of larval midges that make them susceptible to effective control measures.

3. Determine the relationship of salivary components to viral infection.

4. Evaluate methods to control biting midges in order to prevent disease in sheep, deer, and cattle.

5. Determine the relationships between pathogenic and non-pathogenic bacteria and viruses in biting midges, taking advantage of the recently elucidated transcriptome of *Culicoides sonorensis.*

Anticipated Products:

Improved risk assessment	***Improved surveillance***	***Improved control***	***Improved sustainability and monitoring***
✓		✓	

Impact: More reliable production of sheep, deer, and cattle where there is a threat from pathogens transmitted by biting midges

Problem 2G Resources:
The following location has research projects addressing the problem statement identified under Problem 2G:

- Arthropod Borne Animal Diseases Research Unit, Manhattan, KS

Component 3: Fire ants and other invasive pest ants

Pest ants cause severe damage in agricultural and urban sectors and often negatively impact natural environments. The majority of pest ants are invasive species. In the agricultural sector, ants have been shown to reduce crop yields and harm livestock by attacking small or newborn farm animals, like chicks or calves. Such attacks lead to physical damage, increased stress, and the potential death of these animals. Numerous high-value crop plants have been directly affected by ant feeding including soybeans, corn, okra, potatoes, almonds, and citrus. Even farm equipment and irrigation systems have been damaged by pest ant species. The predatory nature of ants may also harm plants or crop production by reducing the density of pollinators and other beneficial insects, such as natural enemies. Certain species increase the densities of sap-sucking pest insects (aphids and coccids) that transmit diseases directly or encourage growth of molds on important crops such as grapes and citrus. Pest ant-contaminated shipments into domestic or foreign controlled areas are subject to rejection and return to their point of origin. Ants also are the most common arthropod pests in urban environments and account for more complaints to pest control companies than any other insect. In natural environments, invasive ants often displace native ant fauna, reduce arthropod biodiversity, and potentially disrupt entire ecological communities as invading "ecosystem engineers" due to their dominance and the varied functional roles they have in ecosystems.

Customers and stakeholders recently identified ten ant species, most of which are invasive, that require extensive applied and basic research to develop more effective methods for control and management. These included: imported fire ants, Argentine ants, crazy ants, electric ants (little fire ants), carpenter ants, Asian needle ants, white-footed ants, odorous house ants, dark rover ants, Pharaoh ants, and big-headed ants.

Problem Statement 3A: Invasive fire ants
Fire ants are considered major agricultural, medical, urban, and environmental pests in the United States. Imported fire ants currently infest over 350 million acres from Virginia south to Florida and west to California. Beyond the continental United States, these invasive ants have expanded into Puerto Rico, most of the other Caribbean islands, Australia, Taiwan, and China. Agricultural, economic, and medical costs due to fire ants exceed $6 billion dollars annually in the United States and commercial chemical treatments for control are estimated to cost as much as $40 per acre. The affected urban and agricultural sectors are broad in range and include households, schools and recreation areas, electric and communication equipment, and animal and plant agriculture. Insecticide-based control is costly and provides only temporary fire ant suppression. Intercontinental comparisons between native (South America) and introduced (United States) fire ant populations have shown significant differences in the biology, genetics, and reproductive behavior of ants from the two areas. These comparative studies have also shown that numerous natural enemies (parasitoids, parasites and pathogens) are associated with fire ants in South America, but only a few of these have been found from invasive fire ants in the United States. Extensive integrated studies are needed to understand biological differences between native and introduced populations and to identify the most appropriate natural enemies to release for sustainable biological control of fire ants. In addition, fire ant-specific control methods (which will not harm native ants) and novel detection methods to facilitate interception of fire ants at quarantine boundaries are needed to reduce continued spread of fire ants.

Research Needs:

1. Discover new natural enemies (parasitoids, parasites and pathogens) from native South American fire ants for potential use as biological control agents of introduced fire ants in the United States.

2. Collect and evaluate potential natural enemies from South American fire ants and release those proven safe in the United States.

3. Design and evaluate bait formulations and mound treatment formulations with pathogens and natural products as the active ingredients.

4. Investigate novel approaches to fire ant-specific control.

5. Develop methods capable of differentiating and detecting numerous fire ant species.

6. Investigate plant-specific factors that negatively impact fire ant feeding or habitation.

7. Evaluate climate related elements of fire ant biology and develop predictions for the next three decades.

8. Investigate behavior-based fire ant management technologies that reduce contact between fire ants and humans or livestock.

9. Improve virulence of fire ant pathogens by selection of strains in ants and in vitro.

Anticipated Products:

Improved risk assessment	***Improved surveillance***	***Improved control***	***Improved sustainability and monitoring***
✓	✓	✓	✓

Impact: Improved and sustainable fire ant control throughout the United States

Problem 3A Resources:

The following locations have research projects addressing the problem statement identified under Problem 3A:

- Imported Fire Ant and Household Insect Research Unit, Center for Medical Agricultural and Veterinary Entomology, Gainesville, FL

- Biological Control of Pests Research Unit, National Biological Control Center, Stoneville, MS

Problem Statement 3B: Invasive crazy ants

The tawny crazy ant, *Nylanderia fulva*, is an invasive ant from South America that develops extremely dense populations in the United States, which inundate and dominate natural, agricultural, and urban landscapes. Tawny crazy ants currently infest 25 counties in Florida, 24 counties in Texas, the island of St. Croix (U.S. Virgin Islands), and are spreading into Louisiana and Mississippi. Tawny crazy ants cause damage to agriculture, natural resources, recreational areas, and residential environments by killing crops, endangering wildlife, reducing biodiversity, infiltrating buildings, and decreasing value and enjoyment of infested lands due to relentless numbers of ants crawling on animate and inanimate objects. In addition, high densities of these ants have resulted in excessive pesticide use, which poses a serious hazard to humans and the environment. Control options for tawny crazy ants are severely limited, mainly dependent on residual insecticide sprays that are problematic in areas like nature preserves where non-target damage to insects is an issue. IPM strategies based on biology, baiting, and biological control are needed to obtain near and long term control of invasive tawny crazy ants.

Research Needs:

1. Discover natural enemies of tawny crazy ants suitable as biological control agents.

2. Develop effective baiting strategies for tawny crazy ants such as timing bait applications relative to sexual brood production and utilizing insect growth regulators in baits.

3. Identify methods of reducing tawny crazy ant food resources and nesting habitats.

4. Evaluate the relationships between tawny crazy ants and other ant species.

5. Investigate the chemical ecology of tawny crazy ants in order to improve surveillance, control, and bait specificity.

Anticipated Products:

Improved risk assessment	***Improved surveillance***	***Improved control***	***Improved sustainability and monitoring***
✓	✓	✓	

Impact: Improved and sustainable control of *Nylanderia* crazy ants

<u>Problem 3B Resources:</u>

The following locations have research projects addressing the problem statement identified under Problem 3B:

- Imported Fire Ant and Household Insect Research Unit, Center for Medical Agricultural and Veterinary Entomology, Gainesville, FL
- Biological Control of Pests Research Unit, National Biological Control Center, Stoneville, MS

Problem Statement 3C: Other invasive pest ants and climate change
Numerous additional ant species are also serious pests of agriculture, residences, and the natural environment, including: electric ants (little fire ants), Argentine ants, big-headed ants, white-footed ants, Pharaoh ants, and Asian needle ants. Many of the technologies developed for imported fire ants and tawny crazy ants may be adapted for use with these and other pest ants. A better understanding of the climatic and habitat requirements of these pest ants will lead to improved predictions of their potential range and where they will cause the most problems. Information about climatic requirements will also permit predictions of how climate change will affect the distribution and abundance of these pests over the coming decades.

<u>Research Needs</u>:

1. Develop more effective control methods for invasive ants adapted from research efforts on fire ants and the tawny crazy ant in cooperation with other ARS and University researchers.

2. Develop models to predict the invasive ants likely to become future pests in the United States and to predict future range expansions of invasive ants already present in the United States.

3. Investigate potential impacts of climate change on invasive ants.

4. Examine the potential for using semiochemicals to enhance bait effectiveness and improve surveillance/detection methods for select pest ants.

<u>Anticipated Products</u>:

Improved risk assessment	***Improved surveillance***	***Improved control***	***Improved sustainability and monitoring***
✓	✓	✓	

<u>Impact</u>: Assessment of threat from invasive ants and development of the means to manage them

<u>Problem 3C Resources:</u>

The following locations have research projects addressing the problem statement identified under Problem 3C:

- Imported Fire Ant and Household Insect Research Unit, Center for Medical Agricultural and Veterinary Entomology, Gainesville, FL
- Biological Control of Pests Research Unit, National Biological Control Center, Stoneville, MS