Veterinary, Medical, and Urban Entomology (NP 104)
Annual Report for 2007

Introduction: 2, 4, 6, 8 Protecting the two- and four-legged from the six- and eight-legged.

Agriculture depends on people, animals, and plants. National Program 104 solves problems that affect people and animals, protecting them from the insects and ticks that cause direct injury or disease. This year the world saw two events that demonstrated the importance of practical research that is sharply focused on these problems. For the first time, Chikungunya virus escaped its normal distribution in the Indian Ocean basin to invade Europe. An outbreak started when a single infected individual from India was bitten by *Aedes albopictus* (the Asian tiger mosquito) in Ravenna, Italy. The recent abundance of this invasive mosquito species in Italy and a large-scale epidemic in Asia combined to create a new equation in favor of Chikungunya. Fortunately, this part of Italy has well-developed mosquito abatement that was able to suppress the mosquito population quickly and thoroughly – there were only 200 human cases of the disease. The second event was the first occurrence of bluetongue virus in the United Kingdom. The previous year had seen a wide scale outbreak of this pathogen of ruminants transmitted by biting midges. Local species of biting midges were capable of maintaining an outbreak of this strain of the virus that, unlike American strains, causes illness in cattle as well as sheep. These events show that there is a need to be ready to respond to vector-borne pathogens of humans and animals in order to prevent damage to public health and to agriculture.

Probably the highest priority problem facing U.S. agriculture in the National Program 104 area is the reinvasion in Texas of the cattle fever tick. During the summer of 2007, over 1000 square miles in five border counties were placed under temporary quarantine because of the detection of established populations of the fever tick. The reinfestation may be as much the fault of deer as it is of cattle; therefore, traditional eradication techniques may not be sufficient. It is estimated that it will take over $13 million in order to clean out these infestations of a tick that had been eradicated from the U.S. since the 1940s. In addition to the hardship and financial strain imposed on local ranchers, the situation raises the possibility that this tick will once again infest cattle from coast to coast in the southern U.S. Large scale outbreaks of bovine babesiosis (Texas cattle fever) would likely result, leading to tremendous financial strain on producers and consumers alike.

ARS has a long history of achievement in this field. In fact, the first discovery of a disease-causing pathogen transmitted by an arthropod was performed by the microbiologist, Theobald Smith, in 1889-1893 while working for the U.S. Department of Agriculture. He found that Texas cattle fever was caused by a protozoan and that the protozoan was transmitted between cattle by a particular kind of tick. Smith's discovery was well-documented and often discussed at the time, leading to the astoundingly significant association of malaria, yellow fever, and dengue to mosquitoes. His discovery also led to an eradication campaign started in the early 1900s that continues to this day, almost eliminating the threat of Texas cattle fever in our country. The importance of mosquitoes as vectors of important diseases caused a renewed interest in accurate taxonomy and, again, USDA was at the center of activity. L.O. Howard, H.G. Dyar, and F. Knab produced the definitive scholarly work on mosquitoes of the Americas, with Knab completing the manuscript in 1918 as he was dying from sand fly-borne leishmaniasis. In 1942 the War Department called on the USDA to develop new insecticides and repellents to protect military personnel from the ravages of scrub typhus and malaria, particularly in the Pacific Theater. Scientists at the Orlando laboratory eventually screened over 20,000 compounds and produced a series of compounds that could be applied to the skin or clothing. Before the introduction of chloramphenicol in 1949, scrub typhus was almost a death sentence and the repellents dimethyl phthalate, ethyl hexanediol, and benzyl benzoate were all that stood between soldiers and this infection. Thanks to USDA scientists Carroll Smith and Harry Gouck, the screening effort in the 1950s found that DEET was a highly effective insect repellent. DEET remains the standard repellent active ingredient today. ARS also developed the current repellent treatment for military uniforms during the 1980s. The Department of Defense has again asked

ARS to produce better products to protect the U.S. military and the agency has responded with a major effort.

No discussion of USDA achievements would be complete without mentioning the research that led to the defeat of the screwworm fly. This fly actively seeks even the smallest wounds in cattle, lays its eggs, and then causes what is often mortal injury to the animals. In 1950, E.F. Knipling began an effort to release sterile males of the fly over huge areas, preventing the females from laying fertile eggs. This technique has been refined greatly over the years, but it continues and has successfully eradicated the fly as far south as Panama. The benefits from this program are almost incalculable, considering the economic benefit to the American beef industry, the relief from animal suffering, and the benefit to small landholders in Mexico and Central America.

National Program 104 saw several milestones this year.

We had our first retrospective assessment in August, which was chaired by Dr. William Reisen of the University of California, Davis. This was followed by our second Stakeholders' Workshop in Denver, 30 Oct-1 Nov 2007, which was attended by 110 participants. Comments were generally supportive of the program. Stakeholders' clearly supported concentrated work on the Asian tiger mosquito, expansion of efforts to more species of ants, stronger and more integrated research on flies, a concerted effort to solve tick problems, and continued emphasis on biting midges. Stakeholders identified the translation of research into useable products as one of our greatest challenges. As a part of this process, full-text copies of all NP 104 publications from 2002-2006 were placed on the National Agricultural Libraries new USDA literature database, AgSpace (http://agspace.nal.usda.gov/).

NP 104 was fortunate to receive funding for a new area-wide pest management project to control the Asian tiger mosquito. Drs. Gary Clark and Dan Kline of the Mosquito and Fly Research Unit are the principle investigators; they will be working closely with Dr. Dina Fonseca or the Vector Biology Center, Rutgers University.

The Screwworm Research Unit was made a part of the Knipling-Bushland U.S. Livestock Insect Research Laboratory. The center of gravity of the SRU remains in the new screwworm production plant in Pacora, Panama, but at least one person is assigned to KBUSLIRL. This arrangement will not only improve collaboration with other laboratories, it will also give SRU personnel a place to cycle while remaining in screwworm research. Other changes included the merger of the Chemicals Affecting Insect Behavior Laboratory with the Biological Control Laboratory to form the Invasive Insect Biocontrol and Behavior Laboratory in the Plant Science Institute, Beltsville, MD. Finally, the Midwest Livestock Research Unit was merged with the Soil and Water Conservation Research Unit to form the Agroecosystem Management Research Unit, Lincoln, NE.

Thanks initially to funding from the Deployed Warfighter Protection (DWFP) program (Department of Defense), a new effort in discovery of insecticides was started based on natural products. Centered at the ARS Natural Products Utilization Research Unit, Oxford, MS, the effort enlists major participation by the University of Mississippi's National Center for Natural Products Research. These products will be funneled into ARS' "Virtual Laboratory" for evaluation and development of new toxicants, funded by DWFP. Funding from DWFP is also channeled through NP 104 to the Areawide Pest Management Research Unit, College Station, TX, for the purpose of studying new insecticide application techniques.

The laboratories that include NP 104 projects are the Agroecosystem Management Research Unit, Lincoln, NE (AMRU, Research Leader: Dr. James Schepers [retired January 2008]); the Animal Parasitic Diseases Laboratory, Beltsville, MD (APDL, RL: Dr. Dante Zarlenga); the Arthropod-Borne Animal Diseases Laboratory, Laramie, WY (ABADRL, RL: Dr. Richard Mayer [retired July 2007]); the Biological Control of Pests Research Unit, Stoneville, MS (BCPRU, RL: Dr. Douglas Streett); the Formosan Subterranean Termite Research Unit, New Orleans, LA (FSTRU, RL: Dr. Alan Lax); the Coordination of National Termite Management Program, New

Orleans, LA (CNTMP, RL: Dr. Frank Guillot); Imported Fire Ant and Household Insect Research Unit, Gainesville, FL (IFAHIRU, RL: Dr. Robert Vander Meer); Invasive Insect Biocontrol and Behavior Laboratory, Beltsville, MD (IIBBL, RL: Dr. Mark Feldlaufer); the Knipling-Bushland U.S. Livestock Insect Research Laboratory, Kerrville, TX (KBUSLIRL, RL: Dr. John George); and the Mosquito and Fly Research Unit, Gainesville, FL (MFRU, RL: Dr. Gary Clark). Collectively, the laboratories presented 114 invited presentations, presented personnel with 12 awards, negotiated 11 new cooperative research and development agreements, filed 10 patents, and received $2,909,800 in extramural funds. Two new scientists started work at the FSTRU: Drs. Dunhua Zhang and Beverley Wiltz.

The following is a summary of accomplishments for NP 104, arranged according to the components of the Action Plan written in 2003.

Component 1: Ecology and Epidemiology

Ticks

Amblyomma americanum is an important tick because it often bites people and it transmits the pathogen responsible for human monocytic ehrlichiosis. A scientist at the Animal Parasitic Disease Research Laboratory, Beltsville, MD, documented that this species is expanding its range northward, having achieved considerable abundance as far north as Maryland.

Termites

The Formosan Subterranean Termite Research Unit, New Orleans, demonstrated that newly collected FST from the field show aggression towards one another. In some colony pairs however, this aggression rapidly declines upon acclimatization in the laboratory. Understanding factors that lead to colony aggression may provide clues as to what limits termite colony foraging territories and provide measures to improve termite bait discovery and ingestion.

Continuing field studies demonstrated that FST colonies survived approximately a month of flooding following Hurricane Katrina. Approximately 80% of the colonies that were present before the flood were still active several months after the flood. Defense against this species will be as important in the newly rebuilt New Orleans as it was before. Other studies of distribution have shown that the FST does not spread rapidly on its own. The implication is that the spread of the termite in the southeastern U.S. is highly dependent on human moving infested material.

Biting Midges

ABADRL has been working on the relationship between vesicular stomatitis virus and the vectorial status of *Culicoides* biting midges. They have been able to extract saliva and examine its role in the infection process. They have also looked at vertical transmission of this virus in *Culicoides*.

Mosquitoes

The Arthropod-Borne Animals Diseases Research Laboratory, Laramie, WY, has recently begun work on the threat of Rift Valley fever virus introduction to the U.S. This virus is transmitted by mosquitoes in its home range of Africa. Although much more work is necessary, initial tests performed twenty years ago by the U.S. Army showed that at least several species of U.S. mosquitoes are competent vectors of Rift Valley fever virus. The initial colonization of three mosquito species (*Aedes vexans, Aedes dorsalis* and *Culex tarsalis*) has been completed. These species were selected because of initial indications of vector competence and because of their abundance in cattle-growing areas of the western U.S. Establishing the techniques to colonize these mosquitoes requires skill and patience, because larvae have particular rearing requirements and adults do not mate in cages. These insects can now be used for research on

virus-vector-host interactions at the ABADRL, and for studies that will be done on Rift Valley Fever virus vector competence.

Filth Flies

In a collaborative project between an entomologist from the Mosquito and Fly Research Unit, Gainesville, FL, and an ARS research immunologist at the Southeast Regional Poultry Laboratory, Athens, GA, house flies became infected with Salmonella enterica within 24 hours of being released into a room with infected chickens. Dissection of flies revealed presence of the pathogen on the surface and in the midgut but not in the crop or salivary glands. Healthy birds became infected by ingesting as few as five of these naturally-infected flies. The results provide evidence that flies may play a significant role in the movement and transmission of this important pathogen of poultry and humans.

Component 2: Detection and Surveillance Technology

Ticks

The cattle fever tick, *Rhipicephalus* (*Boophilus*) *microplus* was eradicated from the United States by systematically dipping cattle and placing quarantines on infested pastures. Eradication is important because this tick is the sole vector of bovine babesiosis in the U.S.; therefore, elimination of the tick eliminates the threat of this important disease of cattle. One of the threats to programs designed to prevent the tick from being reintroduced on infested cattle from Mexico is the development of resistance to acaricides. The Knipling-Bushland U.S. Livestock Insects Research Laboratory (KBUSLIRL), Kerrville, Texas, made significant progress in understanding the origins of resistance and how to detect it. They found that the tick produces three kinds of acetylcholinesterase, the first such discovery in any arthropod. This implies that organophosphate acaricides have three potential enzymes to attack and also that the tick has some redundancy in its response to those acaricides. The KBUSLIRL also developed a rapid DNA-based assay to detect gene mutations that change octopamine receptors, which are the targets of formamidine acaricides. Finally, ARS scientists examined the sensitivity of commonly used bioassays to show that some do not provide useful information for documentation of resistance or susceptibility.

Biting Midges

Research progress continues at the Arthropod-Borne Animal Diseases Research Laboratory, Laramie, WY, on the development of improved diagnostics for arboviruses. Scientists optimized a method for measuring the amount of bluetongue virus (BTV) in *Culicoides* cell culture, a capability that will improve the chances for early detection of exotic serotypes of BTV. A very sensitive method for detection of BTV RNA using markers that fluoresce in the infrared light range was applied to detection of epizootic hemorrhagic disease virus (EHDV), an important pathogen on deer farms. Solid phase detection of RNA developed in collaboration with an industrial partner may provide even more sensitive and quick methods for detection of these viruses. Sequencing of the genomes of BTV and EHDV is providing new targets for viral detection.

Phlebotomine Sand Flies

Multiple lures were tested in MMX mosquito traps (a commercial design that blow out vapors of an attractant near the point where insects are sucked in) for their ability to enhance the capture of phlebotomine sand flies. A human odor sample, octenol, and carbon dioxide were tested in a Latin square design in Aswan, Egypt. Preliminary results indicate that human odors and octenol lures in MMX traps increased the capture of *Phlebotomus papatasi*, a vector of leishmaniasis in the Middle East. Experiments are in progress to examine effects of trap orientation on capture of sand flies.

Mosquitoes

Mosquito-borne diseases pose a significant threat to the health of animals and people. One of these diseases, Rift Valley fever (RVF), causes high mortality and abortion in domestic animals, and significant fever, meningoencephalitis, hemorrhage and mortality in humans. To prevent potential introduction of this disease into the United States, it is important to detect and respond to outbreaks in natural settings in Africa and the Middle East. Scientists at the Mosquito and Fly Research Unit, Center for Medical, Agricultural and Veterinary Entomology in Gainesville, FL, have discovered a method, using global and local climate and vegetation development information, to forecast this disease well before it occurs. In late-2006, an early warning of an impending RVF outbreak was issued to national and international agricultural and public health officials 3 months before a large outbreak occurred in four countries in the Horn of Africa. This outbreak affected thousands of people and hundreds of thousands of domestic animals; dramatically impacting the economy of these countries. This alert resulted in increased national and international surveillance and dramatically enhanced the RVF control response for the first time in history; reducing the impact of the disease and protecting other countries from becoming affected by the disease. This research product will become the standard model for predicting RVF and will be used as a template for new research to develop similar models for the United States for other important mosquito-borne diseases.

MFRU and CMAVE have taken a central role in organizing the response to potential introductions of Rift Valley fever virus or other exotic, arthropod-borne pathogens. Although US agencies and universities are actively creating response/surveillance plans for RVFV and researching critical technological advances such as diagnostics and vaccines, there is a risk of confusion and delay due to lack of communication and/or integrated response efforts should RVFV arrive in the US. MFRU staff organized key researchers and administrators from several federal and state agencies and universities into a Working Group to formulate synthesized response plans, avoid duplicating research, and set a future trajectory that will significantly strengthen the US against the possible arrival of RVFV. A latent but high-value impact of this Working Group is that its products and partnerships will be laterally transferable to other mosquito-borne viruses currently or potentially impacting the US economy and animal and public health.

MFRU has made progress in developing general guidelines for detection of mosquitoes in the U.S. One of the challenges is to know whether or not a mosquito has expanded its range. Another is simply to understand where mosquito species occur and how abundant they are at each location. Unbiased estimators are needed to acquire data that can be used to understand and forecast mosquito distributions in time and space and to reliably predict mosquito-borne disease transmission risk. The mechanical traps presently used to monitor mosquito populations for this purpose provide biased estimates of mosquito density. The MFRU has developed a family of preliminary statistical models that explain the relationship between capture rates of adult mosquitoes by mechanical traps and the rate of landing by adult mosquitoes on a human subject. The models allow us to infer mosquito attack rates from mechanical trap data. This capacity is critical to the development of reliable methods for assessing disease transmission risk and for the timely implementation of vector controls that would allow preemption of epizootics/epidemics of mosquito-transmitted disease. Another approach is to use indirect indicators of mosquito abundance to estimate regional susceptibility to infestation and to predict abundance. MFRU has worked on correlation of indicators from remote sensing (satellite imagery) with actual trap counts in the U.S. This work has been applied more specifically to the problem of detection at seaports. With the assistance of local, state, and federal officials, a pilot study site has been identified at the Ports of Charleston, SC and historical mosquito activity data for the Port area are being analyzed. The required permissions necessary to sample arriving vessels, berth areas, and the dockside environment for exotic mosquito vectors and the pathogens they may be carrying are being obtained. The methods and techniques developed in this study will enable surveillance for exotic mosquito species in seaport environments throughout the continental U.S. and will facilitate the detection, containment, and local eradication of exotic and/or invasive mosquito vectors upon arrival in the USA.

Flies

Stable flies (*Stomoxys calcitrans*) are a non-native species of muscid fly that bites a wide variety of hosts. It becomes a pest of cattle in areas where abundant larval sites are created by any of a number of cultural practices. Compost, wastage of hay from round bails, liquid fertilizer on pasturage, and feed lots are among the practices that make larval habitats for this species. Anecdotal reports of flies in the middle of lakes or well off shore in the ocean have created the impression that stable flies travel great distances in the course of their lifetimes. Vigorous movement by this species makes population assessment a particular challenge, as demonstrated by ARS scientists at the Agroecosystem Management Research Unit in Lincoln, Nebraska. During a three-year study, they found that trapping results showing abundant populations were different even half a mile away. The implication is that multiple traps need to be used to get usefully precise measurements of stable fly populations.

In response to a request by U.S. Navy personnel, a comparison was made of nine commercial fly traps, including the only trap ("Flies-be-gone") that currently has a national stock number (NSN). The "Flies-be-gone" trap only collected 7% as many house flies and 16% as many blow flies as the most attractive commercial trap (Farnam's "Terminator") studied. In a follow-up study in July 2007 that evaluated the relative contributions of trap geometry and attractants to fly collection, the "Flies-be-gone" trap did not collect as many flies as the "Terminator," regardless of the attractant used. Results of this study may help guide future decisions as to which traps are most effective in collecting flies and provide the best value for the US military.

Fire Ants

The Biological Control of Pests Research Unit, Stoneville, MS, developed a new and simpler method for distinguishing red and black imported fire ants, as well as their hybrids. They also examined the shape and infrared signature of fire ant mounds in detail in order to be able to detect them from aerial photographs. Existing data from the U.S. Geological Survey was shown to be useful for predicting areas of high fire ant abundance at a field scale. Automated computer detection based on unique mound characteristics discern 80% of fire ant mounds in aerial images, with a false alarm rates of < 4%.

Component 3: Biology and Physiology

Termites

A cooperative agreement with the University of Hawaii funded research that showed that dead termites repel other termites from feeding.

Scientists at the Formosan Subterranean Termite Research Unit, New Orleans, LA, detected the anaerobic bacterium, *Klebsiella pneumoniae*, in the gut of the Formosan subterranean termite (FST). They showed that these bacteria fix nitrogen from the atmosphere in the form of ammonia. Although it remains to be shown that all FST have these bacteria, the evidence suggests that *K. pneumoniae* could be essential for nitrogen fixation in the termite gut.

Phlebotomine Sand Flies

The Arthropod-Borne Animal Diseases Research Laboratory, Laramie, WY, discovered a sand fly species (*Lutzomyia apache*) for the first time in Wyoming. Blood meal hosts and viral infection were examined. Live specimens have been colonized. It is important to study this species because it appears to occur in abundance, but with little visibility to ranchers or entomologists.

Biting Midges

The receptors for bluetongue virus (BTV) were characterized by scientists at the Arthropod-Borne Animal Diseases Research Laboratory. Virus entry into a host cell is a multi-step process that starts with binding and internalization. Investigations into these mechanism(s) have led to the identification of a carbohydrate binding receptor for BTV.

Flies

Variants of a horn fly anti-coagulant, thrombostasin, that were unique to a Texas field collection were identified. The frequency for all variants in horn flies collected from cattle hosts specifically phenotyped as high- or low-carriers of horn flies was evaluated, demonstrating a significant difference between thrombostasin variants of flies collected from these high- versus low-carrier hosts. This contributes to our understanding of what may make one bovine host more suitable for flies than another within the same herd. Specifically, the data suggested that thrombin, the target of horn fly thrombostasin, may differ between hosts and potentially provide a marker for host resistance to the horn fly.

Fire Ants

Fire ant social behavior was linked to variation within a single gene. The fire ant populations in the United States are characterized as consisting of either single queen or multiple queen colonies. The dynamics of the different social systems are important to understand, since the multiple queen type is thought to be more difficult to control. A scientist from the Imported Fire Ant and Household Insect Research Unit, Gainesville, FL, in collaboration with scientists from the University of Georgia, showed that the variation in fire ant social behavior, the tolerance of multiple queens in a single colony, can be attributed to three critical amino acid changes within a single protein. This study yielded information useful in bridging functional and population genetic approaches to understanding the genetic basis of an important social trait.

Component 4: Control Technology

Ticks

Scientists at the KBUSLIRL showed that cattle fever ticks resistant to either permethrin (a pyrethroid acaricide) or amitraz (a formamidine acaricide) were sensitive to a combination of the two chemicals. Use of a mixture of acaricides on cattle may provide the means to control tick populations that are currently resistant. What is more, mixtures may have the effect of reversing resistance in the population.

Maintenance of the cattle fever tick quarantine zone along the Texas-Mexico border is critical to protecting the U.S. cattle industry against these ticks and the disease agent causing Texas fever that they transmit. In an effort by the Knipling-Bushland US Livestock Insects Research Laboratory, Kerrville, TX, to develop improved control technologies and strategies, they demonstrated that pastured cattle fed ad lib liquid molasses containing ivermectin resulted in serum concentrations of the drug sufficient to control all of the fever ticks feeding on the animals (>10ppb). This technology, if used strategically in the Cattle Fever Tick Eradication Program in combination with other technologies developed at our laboratory, should enable continued control of outbreaks of this serious pest that continue to be re-introduced across the Rio Grande and into the U.S. from Mexico. The use of ivermectin-medicated molasses offers potential to minimize the cost of the current method of gathering and dipping cattle at 2-week intervals for 6-9 months or vacating cattle from pastures.

Scientists at the Animal Parasitic Diseases and the Invasive Insect Biocontrol and Behavior Laboratories, Beltsville, MD, and the Natural Products Utilization Research Unit, Oxford, MS, worked on a range of compounds that disrupt the host-seeking and feeding process of the ticks that transmit Lyme disease and the ticks that transmit human monocytic ehrlichiosis. The

laboratories participated in the discovery of a range of compounds originally of botanical origin, including some provided by a collaborator associated with the Smithsonian Institution. One compound, isolongifolenone, has been submitted for a patent application. Some of the same compounds were also effective against mosquitoes.

Termites

The Coordination of National Termite Management Program, New Orleans, Louisiana, was started to address the problem of Formosan subterranean termite (FST) infestation in the French Quarter of New Orleans. This historical area of the U.S. contains many 18th and 19th century buildings of considerable cultural importance, but the importation of the invasive FST threatened them with destruction. The program has used a combination of monitoring and gradual, systematic expansion to target control efforts effectively. Some of the control and surveillance techniques have been developed as a part of this project. As of July 2007, 95% of the original colonies of FST in the treated portion of the French Quarter had been destroyed. The program has developed an extensive system of communication with the public, pest control operators, and municipal authorities in order to implement the trial control plan. Unfortunately, the FST continues to spread throughout the southeastern U.S. As a model, the New Orleans program has produced lessons for expansion of area-wide pest management of the FST anywhere in the nation.

Scientists at the University of Hawaii funded through an ARS cooperative agreement showed that wood treated with boron-containing disodium octaborate tetrahydrate, the standard preservative treatment in Hawaii, effectively protected the wood. They observed that termites transfer a significant amount of boron to non-feeding members of the colony, potentially extending the effectiveness of the wood treatment beyond those individual termites that first eat the wood. Elimination of a colony would require long-term exposure, as short-term exposures are not always lethal to the termites.

The Formosan Subterranean Termite Research, New Orleans, LA, has made progress in identifying new toxicants from natural sources. Additional volatile natural products from crops have been isolated and identified that are toxic to termites. Analogs of these chemicals have been tested and structure/function studies have been conducted showing the essential chemical features required for toxicity. These chemicals also might prove useful as environmentally friendly yet effective compounds to kill termites in wall voids or in the hollows of infested trees. Work also continues on the identification of toxic metabolites from *Metarhizium* fungus species and chemical fractionation indicates a multi-component nature of the toxin(s). Effective transformation of *Paecilomyces*, another fungal biological control agent will allow us to follow the progression of the fungal infections and determine whether cultural conditions or amendments to the biological control formulation can improve infection of the termites and thereby improve biological control. Keratin-based foam developed by ARS continues to be the best way to apply *Paecilomyces* spores inside trees for treatment of FST infestations. Identification of toxic chemicals from biological control fungi may also provide the basis for new chemical classes of termiticides or new target sites for such chemicals. In a related finding, a fungal extract applied to filter paper has showed feeding stimulating activity compared with untreated controls. Chemical fractionation has revealed a single active fraction that also stimulates feeding and may be useful in a baiting system. Further fractionation and characterization of the active molecules are in progress. Discovery of feeding stimulants could increase the amount of bait consumed by termites and improve the effectiveness of baits as termite control treatments.

Mosquitoes

The Arthropod-Borne Animal Diseases Laboratory, Laramie, WY, worked on a new West Nile virus vaccine that would protect horses and, potentially, humans. The vaccine is based on recombinant proteins produced by mammalian cells. Mice are being used to optimize dosage rates required to generate neutralizing antibodies.

ARS scientists at the Mosquito and Fly Research Unit, Gainesville, FL, performed research that contributes to current and future capabilities for mosquito and fly control. They have discovered methods to utilize molecular biology techniques for development of biopesticides that target specific critical pathways in mosquitoes. Using the programmed cell death pathway as a target, scientists have constructed double-stranded RNAs (dsRNAs) that can be topically applied to kill female *Aedes aegypti*. This work has resulted in a provisional patent. Two additional mosquito attraction inhibitors (compounds that prevent mosquitoes from finding their hosts) were discovered, adding to the 24 compounds submitted for a provisional patent last year. A provisional patent application was also filed for a seven-component blend that is highly attractive to house flies. This blend has the advantages of being completely defined (in contrast to extracts) and of having low odor characteristics to people. Quantitative structure activity relationship (QSAR) modeling methods were used to model chemical characteristics of highly efficacious repellents from the USDA archives of chemical analyses accumulated over the past 60 years. A total of 23 novel compounds were synthesized and included in bioassays with 11 compounds identified from archived data. The results of the cloth-patch bioassay screening identified many compounds whose duration of repellency was substantially longer than that provided by DEET (i.e., DEET provided protection for 7 days while these new compounds provided >40 days of protection). These new experimental observations were reinserted into the model and the resultant predictions demonstrated a high correlation between the model's theoretical predictions and observed results. The laboratory began examination of sugar baits for mosquitoes, including tests against three different genera. This strategy has promise because it attacks the adult population of mosquitoes during a part of their lives that are usually untouched by other methods. Another novel method to kill mosquitoes was development of viral protein ligands that are involved in the infection process. Forty-four structural viral proteins were examined, resulting in four proteins of significance.

Flies

The horn fly (*Haematobia irritans*) is notorious for its ability to develop resistance to insecticides. Scientists at KBUSLIRL characterized the gene responsible for production of acetylcholinesterase, which is a first step in being able to detect resistance to organophosphate insecticides. They also examined horn fly populations in the state of Matto Grosso del Sur in Brazil, an area where horn fly is an invasive pest introduced from the United States. They found widespread cypermethrin resistance – up to 705 fold less susceptibility than in normal populations. This resistance was not due to two of the most common physiological mechanisms, suggesting that this strain of horn fly could represent a threat to the U.S. were it to be introduced from Brazil. This situation is an illustration of how the exportation of invasive pests from the U.S. can eventually result in selection of characteristics in the pest that make it more damaging than in its native range.

Horn flies (*Haematobia irritans*) spend most of their adult lives on cattle, leaving the host only briefly to oviposit on freshly deposited feces. The flies survive on blood from the cattle, creating significant irritation for the animal when economic thresholds above 200 flies/animal are reached. Scientists at KBUSLIRL worked out a method for controlling the fly larvae in the feces by feeding cattle with molasses laced with doramectin (a macrocyclic lactone). The treated molasses was used for three weeks, and then withdrawn until flies again reached the economic threshold.

The Screwworm Research Unit, Pacora, Panama, handed over a new strain of screwworm fly, JAMAICA-06, to APHIS for its mass rearing of sterile males. This was the first example of strain development performed under the direction of ARS scientists but performed by APHIS-employed technicians. The cellulose based diet developed by ARS scientists was fully integrated into rearing practices. The unit completed the first year of research funded by APHIS to develop a male-only strain of screwworm fly. The first milestones of this program were achieved by completing an EST genomic library of the horn fly, which will be used as a model system. Thanks to increased communication with relevant APHIS partners, the operational use of cryopreservation is also being explored.

MFRU has also done work on biocontrol of filth flies. A new viral pathogen of house flies (salivary gland hyperplasia virus) is being developed as a biocontrol agent. The diapriid fly parasitoid, *Trichopria nigra,* was originally obtained from stable fly pupae in Russia and Kazakhstan. In the absence of experience with any host material, this species is strongly attracted to pupae of the house fly, stable fly, horn fly, black dump fly and flesh flies. Behavioral studies have demonstrated that 24 hours of conditioning of young parasitoids on one species strongly influences the attractiveness of that species in subsequent exposures. The results may facilitate mass production of this species and lead to ways to improve the effectiveness of released biocontrol agents against intended target species. *Tachinaephagus zealandicus* is a parasitoid of muscoid fly larvae and is native to the Southern Hemisphere, where it is regarded as an important biocontrol agent for filth flies. Although this species was released in California in the 1960's, there is little information on the status of its establishment in the US. In 2007, a survey for *T. zealandicus* was conducted at various locations in the eastern US. Traps baited with larvae of a flesh fly (*Sarcophaga bullata*) were placed for 24 hours in woodland, riverine, and open field habitats near livestock farms. Results of the survey demonstrated that this species is well-established in Kentucky, Tennessee, North Carolina, Georgia and Florida. Eight geographic isolates of *T. zealandicus* are now in culture and will be evaluated for fitness before selecting a strain for further development as a biocontrol tool. This discovery eliminates the regulatory barriers to importing an exotic species and will facilitate rearing and release of healthy, locally-adapted parasitoids for fly biocontrol.

The MFRU also worked on evaluation of traps for house fly control under desert conditions, similar to those experienced by U.S. military personnel in the Middle East, concluding that wet-based traps work much better than dry-based traps.

Fire Ants

Progress on management of the imported fire ants included documentation of the spread of the biocontrol agent, *Pseudacteon tricuspis*, throughout Florida. This small phorid fly that develops inside the red imported fire ant was discovered by scientists at the Imported Fire Ant and Household Insects Research Unit, Gainesville, FL. They have been working with APHIS to distribute the fly. A chemical blend that synergistically stimulates the phorid flies to attack fire ants was developed to improve rearing efficiency of the biocontrol agent. The unit also discovered the second virus known from the red imported fire ant. The entire genome was sequenced and studies suggest that the virus (SINV-2) could potentially serve as a sustainable biological control agent for fire ants. Another pathogen of fire ants is a protozoan, *Vairimorpha invictae*. Currently the pathogen is in quarantine. To obtain permission to release this pathogen it is important to demonstrate that it does not infect fire ant species native to the U.S. Laboratory host specificity tests of this fire ant pathogen indicated that the protozoan pathogen does not infect native North American fire ants. These data will be used to apply to APHIS for release in the United States. The Biological Control of Pest Research Unit, Stoneville, MS, developed new compounds of natural origin for control of fire ants. The laboratory's phorid rearing and release program has resulted in the expansion of the range of the biocontrol agent, *Pseudacteon curvatus*, throughout the range of hybrid and black fire ants in Mississippi.

The six-year project on area-wide suppression of fire ants concluded this year. The high value demonstration sites established a working relationship between ARS and property managers so that both parties may design a practical fire ant management plan that accommodates customers' budget and unique land-use needs. It is intended that customers will adopt methods and technologies demonstrated at high value sites. By committing to a one-year work plan, ARS co-operators have demonstrated effective fire ant control strategies that address the needs of a diverse group of customers including (but not limited to) parks, camp grounds, schools, and golf courses. One measure of the success of the project was that at the conclusion of the work plan, customers at Oklahoma and Florida high value sites indicated they would adopt ARS methods and technologies demonstrated at individual sites. The Florida customers intend to purchase

appropriate equipment and apply demonstrated methods to potentially 26 parks that they manage.

Bibliography for July 2006 through June 2007.

The list of articles produced by each laboratory during this period does not necessarily reflect the accomplishments discussed above. Publications in entomology commonly require a year for publication, putting them out of phase with the work itself. Nonetheless; publications are the most important output of our research because they form the body of knowledge that will be used to improve agriculture for generations to come. Those publications marked with an asterix (*) were shared between research units, indicating active collaboration. Publications produced by a collaborator funded by ARS and without an ARS scientist as author are not listed.

Agroecosystem Management Research Unit, Lincoln, NE

Articles per full-time scientist: 1.5

*Berkebile, D.R., Sagel, A., Skoda, S.R., Foster, J.E. 2006. Laboratory environment effects on the reproduction and mortality of adult screwworm (Diptera: Calliphoridae). Neotropical Entomology. 35(6):781-786.

*Carlson, D.A., Berkebile, D.R., Skoda, S.R., Mihok, S. 2007. Candidate sex pheromones of the new world screwworm *Cochliomyia hominivorax*. Medical and Veterinary Entomology. 21(1): 93-96.

Taylor, D.B., Berkebile, D.R., Scholl, P.J. 2007. Stable fly population dynamics in eastern Nebraska in relation to climatic variables. Journal of Medical Entomology. 44(5): 765-771.

Animal Parasitic Diseases Laboratory, Beltsville, MD

Articles per full-time scientist: 3.0

Carroll, J.F. 2007. A note on the occurrence of the lone star tick, *Amblyomma americanum* (Acari: Ixodidae) in the greater Baltimore-Washington area. Proceedings of the Entomological Society of Washington. 109(1):253-256.

*Carroll, J.F., Cantrell, C.L., Klun, J.A., Kramer, M.H. 2007. Repellency of two terpenoid compounds isolated from *Callicarpa americana* (Lamiaceae) against *Ixodes scapularis* and *Amblyomma americanum* ticks. Experimental and Applied Acarology. 41:205-224.

Weldon, P.J., Carroll, J.F. 2007. Vertebrate chemical defense: secreted and topically acquired deterrents of arthropods. In: Debboun, M., Frances, S.P., and Strickman, D., editors. Insect repellents: principles, methods, and uses. Boca Raton, FL: CRC Press. p. 47-75.

Arthropod-Borne Animal Diseases Research Laboratory, Laramie, WY

Articles per full-time scientist: 1.5

Kato, C.Y., Mayer, R.T. 2007. An improved, high-throughput method for detection of bluetongue virus RNA in *Culicoides* midges utilizing infrared-dye-labeled primers for reverse transcriptase PCR. J. of Virological Methods, V. 140, Issues 1-2, March 2007, p. 140-147.

Langner, K.F.A., K.E. Darpel, E. Denison, B.S. Drolet, W. Leibold, P.S. Mellor, P.P.C. Mertens, M. Nimtz, I. Greiser-Wilke. 2007. Collection and analysis of salivary proteins from the biting midge *Culicoides nubeculosus* (Diptera: Ceratopogonidae). Journal of Medical Entomology 44(2):238-248.

Schmidtmann, E.T. 2006. Testing the relationship between dissolved salts in aquatic habitats and immature populations of the *Culicoides variipennis* complex (Diptera:Ceratopogonidae). Environmental Entomology 35(5):1154-1160.

Biological Control of Pests Research Unit, Stoneville, MS

Articles per full-time scientist: 2.5

Chen, J. 2006. Qualitative profile of ant-derived chemicals in nests constructed with silica gel by the red imported fire ants. Journal of Chemical Ecology 33:631-642.

Chen, J. 2007. Advancement on techniques for the separation and maintenance of the red imported fire ant colonies. Insect Science 14:1-4.

Vogt, J. T., and W. A. Smith. 2007. Effects of simulated and natural rainfall on summer mound construction by imported fire ants (Hymenoptera: Formicidae). Sociobiology 50: 379-390.

Vogt, J. T. 2007. Three-dimensional method for characterizing ant mounds. Florida Entomologist 90: 553-558.

Vogt, J.T., Oliver, J.A. 2006. Distribution and size of imported fire ant (Hymenoptera: Formicidae) mounds in recently invaded ball-and-burlap nurseries in Tennessee. Journal of Entomological Science 41: 385-393.

Formosan Subterranean Termite Research Unit, New Orleans, LA

Articles per full-time scientist: 1.4

*Bland, J.M., Raina, A.K., Carpita, A., Dickens, J.C. 2007. Comparative analysis of 3,6,8-dodecatrien-1-ol from three subterranean termite species. Sociobiology 50(2):535-531.

*Chauhan, K.R., Raina, A. 2007. Effect of catnip oil and its major components on the Formosan subterranean termite. Biopesticides International 2(2):137-143.

Doolittle, M., Raina, A.K., Lax, A.R., Boopathy, R. 2006. Effect of natural products on gut endosymbiotic microbes in Formosan subterranean termites. International Biodeterioration and Biodegradation. 59:69-71.

Khamraev, A., Lebedeva, N., Zuginisov, T., Abdullaev, I., Rakhmatullaev, A., Raina, A.K. 2007. Food preferences of the Turkestan termite *Anacanthotermes turkestanicus* (Isoptera: Hodotermitidae). Sociobiology 50(2):469-478.

Raina, A.K., Lupiani, B. 2006. Acquisition, persistence and species susceptibility of the Hz-2V virus. Journal of Invertebrate Pathology. 93:71-74.

Raina, A.K., Bland, J.M., Doolittle, M., Lax, A.R., Boopathy, R., Folkins, M. 2007. Effect of orange oil extract on the Formosan subterranean termite (Isoptera: Rhinotermitidae). Journal of Economic Entomology 100(3):880-885.

Raina, A.K., Murphy, C.A., Florane, C.B., Williams, K.A., Park, Y.I., Ingber, B.F. Structure of spermatheca and sperm dynamics in the Formosan subterranean termite *Coptotermes formosanus* (Isoptera: Rhinotermitidae). 2007. Annals of the Entomological Society of America. 100:481-424.

Imported Fire Ant and Household Insect Research Unit, Gainesville, FL

Articles per full-time scientist: 2.4

Barron, A.B., Maleszka, R., Vander Meer, R.K., Robinson, G.E. 2007. Octopamine modulates honey bee dance behavior. Proceedings of the National Academy of Sciences. 104(5):1703-1707.

Barron, A.B., Maleszka, J., Vander Meer, R.K., Robinson, G.E., Maleszka, R. 2007. Comparing injection, feeding and topical application methods for treatment of honey bees with octopamine. Journal of Insect Physiology. 53(2):187-194.

Briano, J., Calcaterra, L., Valles, S.M., Livore, J., Vander Meer, R.K. 2006. New survey for the fire ant microsporidia *Vairimorpha invictae* and *Thelohania solenopsae* in southern South America, with observations on their field persistence and prevalence of dual infections. Environmental Entomology. Volume 35 (5):1358-1365.

*Burns, S.N., Vander Meer, R.K., Teal, P.E. 2007. Mating flight activity as dealation factors for fire ant, *Solenopsis invicta*, female alates. Annals of the Entomological Society of America. 100(2):257-264.

Calcaterra, L., Vander Meer, R.K., Livore, J., Pitts, J., Tsutsui, N. 2007. A survey of *Solenopsis* fire ants and their parasitoid flies (Diptera: Phoridae: *Pseudacteon*) in central Chile and central western Argentina. Annals of the Entomological Society of America. Vol. 100, No 4, July 2007 pp. 512-521.

Hashimoto, Y., Valles, S.M., Strong, C.A. 2006. Detection and quantitation of *Solenopsis invicta* virus in fire ants by real-time PCR. Journal of Virological Methods.140(1-2):132-139.

Oi, D.H., Oi, F.M. 2006. Speed of efficacy and delayed toxicity characteristics of fast-acting fire ant (Hymenoptera: Formicidae) baits. Journal of Economic Entomology. 99(5):1739-1748.

Pereira, R., Porter, S.D. 2007. Range expansion of the fire ant decapitating fly, *Pseudacteon tricuspis*, eight to nine years after releases in Florida. Florida Entomologist.89(4):536-538.

Preston, C.A., Fritz, G.N., Vander Meer, R.K. 2006. Prevalence of *Thelohania solenopsae* infected *Solenopsis invicta* newly mated queens within areas of differing social form distributions. Journal of Invertebrate Pathology. 94(2):119-124.

Shoemaker, D.D., Deheer, C.J., Krieger, M.J., Ross, K.G. 2007. Population genetics of the invasive fire ant *Solenopsis invicta* (Hymenoptera: Formicidae) in the U.S.A.. Annals of the Entomological Society of America. 99(6):1213-1233.

Valles, S.M., Porter, S.D. 2007. *Pseudacteon* decapitating flies: potential vectors of a fire ant virus?. Florida Entomologist. 90(1):268-270.

Valles, S.M., Strong, C.A., Oi, D.H., Porter, S.D., Pereira, R.M., Vander Meer, R.K., Hashimoto, Y., Hooper-Bui, L.M., Sanchez-Arroyo, H., Davis, T., Karpakakunjaram, V., Vail, K.M., Fudd, G., Briano, J., Calcaterra, L., Gilbert, L.E., Ward, R., Ward, K., Oliver, J., Taniguchi, G., Thompson, D.C. 2007. Phenology, distribution, and host specificity of *Solenopsis invicta* virus. Journal of Invertebrate Pathology.96(1):18-27.

<u>Invasive Insect Biocontrol and Behavior Laboratory, Beltsville, MD</u>

Articles per full-time scientist: 2.0

*Carroll, J.F., Cantrell, C.L., Klun, J.A., Kramer, M.H. 2007. Repellency of two terpenoid compounds isolated from *Callicarpa americana* (Lamiaceae) against *Ixodes scapularis* and *Amblyomma americanum* ticks. Experimental and Applied Acarology. 41:205-224.

*Chauhan, K.R., Raina, A. 2007. Effect of catnip oil and its major components on the Formosan subterranean termites. Biopesticides International 2(2):137-143.

Klun, J.A., Khrimian, A., Rowton, E., Kramer, M.H., Debboun, M. 2006. Biting-deterrent activity of a deet analog, two DEPA analogs and SS220 applied topically to human volunteers compared with deet against three species of blood-feeding flies. Journal of Medical Entomology. 43:1248-1251.

Tran, K., Chauhan, K.R. 2007. Structural activity of bovidic acid and related compounds as feeding deterrents against *Aedes aegypti*. Biopestic. Int. 3(1):53-57.

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

Articles per full-time scientist: 1.7

Chen, A.C., He, H., Davey, R.B. 2007. Mutations in a putative octopamine receptor gene in amitraz-resistant cattle ticks. Veterinary Parasitology. 148:379-383.

Davey, R.B., Miller, J.A., George, J.E., Klavons, J.A. 2007. Efficacy of a single doramectin injection against adult female *Boophilus microplus* (Acari: Ixodidae) in the final stages of engorgement before detachment. Journal of Medical Entomology. 44(2):277-282.

Guerrero, F., Barros, T. 2006. Role of kdr and esterase-mediated metabolism in pyrethroid resistant populations of *Haematobia irritans irritans* (Diptera: Muscidae) in Brazil. Journal of Medical Entomology. 43(5):896-901.

Guerrero, F.D., Bendele, K.G., Chen, A.C., Li, A.Y., Miller, R.J., Pleasance, E., Varhol, R., Rousseau, M.-E., Nene, V.M. 2007. Serial analysis of gene expression in the southern cattle tick following acaricide treament of larvae from organophosphate resistant and susceptible strains. Insect Molecular Biology. 16(1):49-60.

Guerrero, F., Bendele, K.G., Davey, R.B., George, J.E. 2007. Detection of *Babesia bigemina* infection in strains of *Rhipicephalus* (*Boophilus*) *microplus* collected from outbreaks in South Texas. Veterinary Parasitology. 145:156-163.

Jonsson, N.N., Miller, R.J., Robertson, J.L. 2007. Critical evaluation of the modified-adult immersion test with discriminating dose bioassy for *Boophilus microplus* using American and Australian isolates. Veterinary Parasitology. 146:307-315.

Klafke, G.M., Sabatini, G.A., de Albuquerque, T.A., Martins, J.R., Kemp, D.H., Miller, R.J., Schumaker, T.T.S. 2006. Larval immersion tests with ivermectin in populations of the cattle tick *Rhipicephalus* (*Boophilus microplus*) (Acari: Ixodidae) from State of São Paulo, Brazil. Veterinary Parasitology. 142(3-4):386-390.

Li, A.Y., Chen, A.C., Miller, R., Davey, R.B., George, J.E. 2007. Acaricide resistance and synergism between permethrin and amitraz against susceptible and resistant strains of *Boophilus microplus* (Acari: Ixodidae). Pest Management Science. 63(9):882-889.

Li, A.Y., Guerrero, F.D., Pruett, J.H. 2007. Involvement of esterases in diazinon resistance and biphasic effects of piperonyl butoxide on diazinon toxicity to *Haematobia irritans irritans* (Diptera: Muscidae). Journal of Pesticide Biochemistry and Physiology. 87:147-155

Lohmeyer, K.H., Miller, J.A. 2006. Pathogenicity of three formulations of entomopathogenic fungi for control of adult *Haematobia irritans* (Diptera: Muscidae). Journal of Economic Entomology. 99(6):1943-1947.

Lohmeyer, K.H., Kammlah, D.M., Pruett Jr, J.H. 2006. White eye color mutant in *Haematobia irritans* (Diptera: Muscidae). Annals of the Entomological Society of America. 99(5):966-968.

Miller, R. J., Davey, R.B., George, J.E. 2007. First report of permethrin-resistant *Boophilus microplus* (Acari: Ixodidae) collected within the United States. Journal of Medical Entomology. 44(2):308-315.

Miller, R.J., Davey, R.B., White, W.H., George, J.E. 2007. A comparison of three bioassay techniques to determine amitraz susceptibility in *Boophilus microplus* (Acari: Ixodidae). Journal of Medical Entomology. 44(2):283-294.

Olafson, P.U., Pruett Jr, J.H., Atteberry, H.N., Steelman, C.D. 2006. Thrombostasin isoform frequency in a Central Texas field population of the horn fly, *Haematobia irritans*. Veterinary Parasitology. 142:359-366.

Olafson, P.U., Pruett Jr, J.H., Steelman, C.D. 2007. Association of the bovine leukocyte antigen major histocompatibility complex class II DRB3*4401 allele with host resistance to the lone star tick, *Amblyomma americanum*. Veterinary Parasitology. 145(1-2):190-195.

Oremus, G., Guerrero, F.D., Alison, Jr, M.W., Kimball, M.M., Kim, J.H., Foil, L.D. 2006. Effects of mid-season avermectin treatments on pyrethroid resistance in horn fly (Diptera: Muscidae) populations at three locations in Louisiana.Veterinary Parasitology. 141(1-2):156-164.

Temeyer, K.B., Chen, A.C. 2007. Identification and characterization of a cDNA encoding the acetylcholinesterase of *Haematobia irritans* (L.) (Diptera: Muscidae). DNA Sequence. 18(2):85-91.

Mosquito and Fly Research Unit, Gainesville, FL

Articles per full-time scientist: 2.4

Anyamba, A., Chrétien, J., Small, J., Tucker, C.J., Linthicum, K. 2006. Developing global climate anomalies suggest potential disease risks for 2006 – 2007. International Journal of Health Geographics 5:60-67.

Barnard, D.R., Bernier, U.R., Xue, R., Klun, J., Debboun, M. 2006. Standard methods for testing mosquito repellents. In: Debboun, M., Frances, S.P., Strickman, D. (eds.), *Insect Repellents: Principles, Methods, and Uses*, CRC Press, Boca Raton, FL. pp 103-110.

Becnel, J.J., White, S.E. 2007. Mosquito pathogenic viruses - the last 20 years. American Mosquito Control Association. 23(2)36-49.

Britch, S.C., Linthicum, K. 2007. Developing a research agenda and a comprehensive national prevention and response plan for Rift Valley fever in the U.S. Emerging Infectious Diseases. 13(8):

*Carlson, D.A., Berkebile, D.R., Skoda, S.R., Mihok, S. 2007. Candidate sex pheromones of the new world screwworm *Cochliomyia hominivorax*. Medical and Veterinary Entomology. 21(1): 93-96.

Carlson, D.A., Hogsette Jr, J.A. 2007. Flybrella: a device to attract and kill house flies. Journal of Economic Entomology. 100:483-487.

Chrétien, J., Anyamba, A., Bedno, S.A., Breiman, R.F., Sang, R., Sergon, K., Powers, A.M., Onyango, C.O., Small, J., Tucker, C.J., Linthicum, K. 2007. Drought-associated Chikungunya emergence along coastal East Africa. American Journal of Tropical Medicine and Hygiene 76(3):405-407.

Geden, C.J. 2007. Development of *Spalangia cameroni* and *Muscidifurax raptor* on live house fly pupae and pupae killed by heat shock, irradiation and cold. Environmental Entomology. 36(1):34-39.

Green, T.B., White, S., Rao, S., Mertens, P., Adler, P.H., Becnel, J.J. 2007. Biological and molecular studies of a cypovirus from the black fly *Simulium ubiquitum* (Diptera: Simuliidae). Journal of Invertebrate Pathology 95 (2007):26-32.

Hoel, D.F., Kline, D.L., Allan, S.A., Grant, A. 2007. Evaluation of carbon dioxide, 1-octen-3-o1 and lactic acid as baits in Mosquito Magnet Pro traps for *Aedes albopictus* (Skuse) in North Central Florida.. American Mosquito Control Association. 23(1):11-17.

Kline, D.L., Patnaude, M., Barnard, D.R. 2006. Efficacy of four trap types for detection and monitoring of *Culex* spp. in north central Florida. Journal of Medical Entomology. 43(6):1121-1128.

Linthicum, K., Allan, S.A., Barnard, D.R., Becnel, J.J., Bernier, U.R., Carlson, D.A., Clark, G.G., Geden, C.J., Hogsette Jr, J.A., Kline, D.L. 2006. The USDA-ARS center for medical, agricultural and veterinary entomology: developing new mosquito surveillance and control products. Proceedings and Papers of the Mosquito and Vector Control Association of California, 74:83-86.

Mihok, S., Carlson, D.A., Ndegwa, P.N. 2007. Biting fly responses to NZI traps baited with octenol, phenols and acetone. Medical and Veterinary Entomology. 21(1):70-84.

Perera, O.P., Green, T.B., Stevens, S.M., White, S.E., Becnel, J.J. 2007. Proteins associated with *Culex nigripalpus* nucleopolyhedrovirus (CuniNPV) occluded virions. Virology. 81(9):4585-4590.

Pridgeon, J.W., Olzmann, J.A., Chin, L.S., Li, L. 2007. PINK1 protects against oxidative stress by phosphorylating mitochondrial chaperone TRAP1. PLoS Biol. 5(7):e172.

*Pridgeon, J.W., Meepagala, K.M., Becnel, J.J., Clark, G.G., Pereira, R.M., Linthicum, K. 2007. Structure-Activity Relationships of 33 piperidines as adulticides against *Aedes aegypti* (Diptera: Culicidae). Journal of Medical Entomology. 44(2):263-269.

Quinn, B.P., Bernier, U.R., Geden, C.J., Hogsette Jr, J.A., Carlson, D.A. 2007. Analysis of extracted and volatile components in blackstrap molasses feed as candidate house fly attractants. Journal of Chromatography. A, 1139(2):279-284

Tomberlin, J.K., Rains, G.C., Allan, S.A., Sanford, M.R., Lewis, W.J. 2006. Associative learning of odor with food or blood-meal by *Culex quinquefasciatus* Say (Diptera: Culicidae). Naturwissenschaften. 93(11):551-556.

Welch, C.H., Kline, D.L., Allan, S.A., Barnard, D.R. 2006. Laboratory evaluation of a dyed food marking technique for *Culex quinquefasciatus* (Diptera: Culicidae). American Mosquito Control Association. 22(4):626-628.

Screwworm Research Unit, Pacora, Panama, and Kerrville, TX

Articles per full-time scientist: 1.5

*Berkebile, D.R., Sagel, A., Skoda, S.R., Foster, J.E. 2006. Laboratory environment effects on the reproduction and mortality of adult screwworm (Diptera: Calliphoridae). Neotropical Entomology. 35(6):781-786.

*Carlson, D.A., Berkebile, D.R., Skoda, S.R., Mihok, S. 2007. Candidate sex pheromones of the new world screwworm *Cochliomyia hominivorax*. Medical and Veterinary Entomology. 21(1): 93-96.

Chaudhury, M.F., Skoda, S.R. 2007. A cellulose fiber-based diet for screwworm (Diptera: Calliphoridae) larvae. Journal of Economic Entomology. 100(1):241-245.