Breakout Session Notes and Participant List for the

USDA
Agricultural Research Service (ARS) and Cooperative State Research Education and Extension Service (CSREES)
Medical, Veterinary, and Urban Entomology Stakeholder Workshop

Denver, Colorado

October 30 – November 2, 2007

2, 4, 6, 8: We perform research that protects 2 and 4-legged creatures from 6 and 8-legged arthropods.

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Participant List

Medical Entomology Breakout Sessions
October 30-31, 2007

Facilitators: Daniel Strickman, National Program Leader, NP 104
Gary Clark, Research Leader, Mosquito and Fly Research Unit

Risk Assessment

1. What are the priority arthropod species affecting the commodity (i.e. people are the commodity) within the U.S.?
   - 1.1. Mosquitoes
     - 1.1.1. Need system to prioritize according to pathogen.
     - 1.1.2. Service nuisance needs to support vector protection. May need to target nuisance mosquitoes to develop the tools to better control vector species.
     - 1.1.3. Spring snowmelt mosquitoes, *Ae. vexans,* salt marsh species (*Ae. taeniorhynchus, sollicitans*).
     - 1.1.4. Hardest to control *(Ae. aegypti, albopictus)* in backyard are controlled by source reduction, deserves special mention among the 3200 spp. Competent vector for Chikungunya, secondary WNV.
     - 1.1.5. Prioritize by habitat.
     - 1.1.6. Urban (under insecticide pressure) perhaps should be top of the priority list because they are hard to control: *Ae. aegypti, Ae. albopictus, Cx. tarsalis, Cx. quinquefasciatus, Cx. pipiens, Cx. pipiens* var. *molestus, Cx. erythrothorax* in local situations
     - 1.1.7. Chikungunya virus, potential.
     - 1.1.8. Should not discontinue work with *Cx. pipiens, quinquefasciatus*.
     - 1.1.9. Bridge vectors that potentially carry WNV from birds to humans and horses. There are some 62 spp. possibly involved.
     - 1.1.10. Rice fields: *An. quadrimaculatus s.l., Ps. columbiae, An. arabiensis, Ae. melanimon*, and other floodwater mosquito spp.
     - 1.1.11. Wetlands preservation/restoration mosquitoes, storm water treatment-big problem not being addressed.
     - 1.1.12. Pest encounters from expansion into suburban areas.
     - 1.1.13. *Ae. japonicus*
     - 1.1.14. Potential vectors of Rift Valley fever virus.
   - 1.2. Ticks
     - 1.2.1. *Amblyomma* due to pathogen importance (human monocytic ehrlichiosis)
     - 1.2.2. *Ix. scapularis* and *Ix. pacificus* (Lyme disease)
     - 1.2.3. *Powassan* vectors (*Ix. scapularis, D. andersoni, Ix. cookei*)
     - 1.2.4. European vectors/variants of *B. burgdorferi* – should be looking for these because they will cause a different syndrome, may have a different ecology
     - 1.2.5. *Dermacentor variablis* because of Rocky Mountain spotted fever.
   - 1.3. *Culicoides*
     - 1.3.1. Lack of knowledge of biology although nuisance rather than disease transmitting.
   - 1.4. Other Species

1.4.1. *Stomoxys* flies
1.4.2. Simuliids (Black Flies)
1.4.3. Sand flies (Phlebotominae)
1.4.4. Tabanids
1.4.5. Bed bugs
1.4.6. Head lice (resistant)
1.4.7. Fleas
1.4.8. Brown widow spider/Brown recluse spider

1.5. Priority (Targets) as top 3, but not prioritized within ticks, nor external to top 3.
1.5.1. *Ae. albopictus, Ae. aegypti*
1.5.2. Ticks:
1.5.2.1. *Ixodes* and Lyme disease
1.5.2.2. *Amblyomma*
1.5.2.3. *D. variablis*
1.5.3. Other urban mosquitoes
1.5.4. Bed bugs
1.5.5. Mechanical vectors (flies, cockroaches)

2. What are the priority arthropod species that might invade the U.S. and disrupt commodity production?
2.1. Not a reasonable direction because so difficult to predict.
2.2. Cx. tritaeniorhynchus
2.3. Exotic pathogen more of concern than exotic species. Likely route would be via airline. No effort to control mode of entry in US because no permethrin treatment of aircraft nor disinsection.
2.4. Disinsection procedures and devices to prevent invasives.
2.5. Risk assessment for high risk routes/prioritize geographical region.
2.6. Response protocol once the insects arrive.
2.7. Consensus not to necessarily target species but process, e.g. control issue of what can be done to containers to reduce likelihood.
2.8. Flood water mosquitoes that have resistant, transportable eggs
2.9. Ticks on exotic animals
2.10. Tick-borne encephalitis virus
2.11. Japanese encephalitis virus
2.12. *Anopheles gambiae.*
2.13. Potential for locally transmitted *Plasmodium* in the U.S.

3. Is there a need for economic analysis of damage from any of these arthropods?
3.1. Bed bugs
3.2. Ae. albopictus
3.3. Culicoides
3.4. Major ones-no need for analysis (straightforward for those that transmit pathogens)
3.5. Indirect effects
3.6. Bites in general

3.7. RVF
3.8. Economic analysis of risk from vectors, of benefit from mosquito control.
3.9. Importance of public perception.
3.10. Use daily adjusted life years to assess impact.

4. What do we need to find out about these species in order to understand their potential for damage?
   4.1. Insecticide resistance
   4.2. Insecticide susceptibility and genomics of insects' reactions
   4.3. Vectorial capacity
   4.4. Economic (or impact) thresholds for biting pests, including for transmission
   4.5. Which are the best indicator species for initial development of a toxicant
   4.6. Changes in species distribution over time

5. What tools would be useful for risk assessment of these species?
   5.1. Remote sensing of vectors and disease outbreaks, similar to Linthicum's work with RVFV
   5.2. GIS predictive and risk assessment models. Climatic forecasting
   5.3. GIS and other tools to inform public
   5.4. New tools for blood meal identification in mosquitoes and ticks
   5.5. IR identification of vectors (same technology as that used for infested grain)
   5.6. Dipstick to distinguish *Cx. pipiens* from *Cx. restuans*

6. How can genomic studies be integrated into this topic?
   6.1. Concentrate on high priority numbers in #1.
   6.2. Genetics seem to have no impact on disease transmission. Not on near horizon.
   6.3. Imbalance in funds to genome research, and other projects.
   6.4. One use of resources could be to develop genomics to streamline insecticide resistance and pesticide compound development, modes of action, and phagomones.
   6.5. Identification
   6.6. PCR-Mass spec for identification of vectors and pathogens
   6.7. Blood meal identification and intraspecific relatedness
   6.8. Identification of sugar meal source
   6.9. Field identification of pathogens in vectors

Surveillance

1. What are the gaps in our ability to detect priority arthropods?
   1.1. General
      1.1.1. Statistics and methods for quantifying populations at low density. Standardized guidelines for sampling to detect clusering refugia and low levels of populations

1.1.2. Better traps, studies to understand species by species advantages and disadvantages of each trap type
1.1.3. Better understanding of trap placement and its relationship to survey results
1.1.4. Trap specificity vs sensitivity
1.1.5. Use of wing beat frequency for identification and characterization
1.1.6. Spotty distribution of records within the U.S.
1.1.7.

1.2. Ticks
1.2.1. Compared to mosquitoes, better estimates of tick population with drags. Problem is getting entomologists everywhere.
1.2.2. Spatial statistic problem. How to convert point data to area data; data analysis.
1.2.3. Tick (ID) Harry Hoogstraal collection at Georgia Southern.
1.2.4. Survey of *Ix. scapularis* in eastern U.S.

1.3. Ae. aegypti and *albopictus*
1.3.1. Tools for collecting adults, need better traps, and more species specific.
1.3.2. System to identify by eggs and differentiate eggs; chemical technique, immunoassay technique?
1.3.3. Ovitrap competition with other sites.
1.3.4. No good tool for measuring *Ae. aegypti* density, other than backpack in house. So, priority is having a low tech adult collection tool would be beneficial.
1.3.5. Sticky adult sampling ovitrap, e.g. the ones currently used in Australia.
1.3.6. Less labor intensive traps, more automation, even automated counting if possible.
1.3.7. No plan to deployment locations of traps? Can error be quantified-what proportion is being sampled? Investment into better understanding what the sampling efficiency is using the current traps.
1.3.8. Methods of detecting mosquito activity (time, bloodfed or not).

1.4. Other urban mosquitoes
1.4.1. Less labor intensive traps, more automation, even automated counting if possible. Can technology be adapted for this purpose? Remote sensing of larval sites (see 1.2.6)
1.4.2. No plan for deployment locations of traps? Can error be quantified-what proportion is being sampled? Investment into better understanding what the sampling efficiency is using the current traps. (see 1.2.7)
1.4.3. Methods of detecting mosquito activity (time, bloodfed or not).
1.4.4. Need better identification tools, emphasize centers of identification, repository of specimen vouchers.
1.4.5. Examine *Cx. pipiens* and other complexes? Mosquito systematics.
1.4.6. Larval traps, detection.

1.5. Bed bugs
1.5.1. Current sticky trap. Perhaps research an attractant or pheromone.

1.6. Mechanical vectors (flies)
1.6.1. Currently have robust program in fly sampling or killing. Stay the course.

1.6.2. Meeting need (existing technology) in livestock work could be adapted easily to the public health setting.

2. What are the gaps in our ability to detect pathogens transmitted by priority arthropods?
   2.1. DHS already functions heavily in detection of this area.
   2.2. ARS may not need to pioneer this area but should apply it, CDC has panels for detection of any known arbovirus.
   2.3. Ticks-one gap, broader detection of pathogens/pathogen discovery. Don't know full range of pathogens in ticks.
   2.4. Immediate *Borrelia burgdorferi* test.
   2.5. Whole area from mosquito attractants to carbohydrate resources is wide open.
   2.6. Quality control of PCR-based detection of pathogens, including issue of live vs dead virus.
   2.7. Guidelines for determining risk, especially when to have confidence that pathogen is absent
3. Are there products already invented that need to be transferred to industry or other user groups?
   3.1. In general, there is a challenge in serving limited markets. Technically useful products sometimes taken off the market because sales are low.
   3.2. Pyriproxifen in a lethal ovitrap for mosquitoes in *Stegomyia*
   3.3. Low density microarrays for the assessment of insecticide resistance.
   3.4. Internet database with insecticide resistance
4. How can we develop new or improve existing surveillance systems for priority arthropods and the pathogens that they transmit?
   4.1. Methods for sufficient surveillance at ports and airports.
   4.2. Sampling methods for containerized freight.
   4.3.
5. How can we improve surveillance systems for potentially invasive species?
   5.1. Link up with DHS for this component to detect what is coming in—pretty much open door.
   5.2. Systematics-improved tools to identify species.
6. How can genomic studies be integrated into this topic?
   6.1. Useful in determining origin of mosquitoes, phylogenetic classification.
7. Multiple pathogen, blood meal, species identification (mosquitoes). (added on 31 October)

Control

1. Do we need any of the following for priority arthropods?
   1.1. General
      1.1.1. Toxicants with new modes of action.
      1.1.2. Innovative delivery and formulation of existing active ingredients.
      1.1.3. Environmental safety is important.
      1.1.4. Consider organic farming market that requires "non-toxic" compounds.
   1.2. New control (and what kinds)-Ticks

1.2.1. Need better delivery systems, formulations, acaricides (applicable to all ticks).
1.2.2. Welcome change-biocontrol research, parasitoids—never been a serious effort to examine them. Still stuck with pesticides only for control.
1.2.3. New effective tick repellents, behavioral modification to stop questing in the neighborhood (anti-phagomones), and new delivery systems for those repellents.
1.2.4. Long term alternative clothing treatment other than permethrin.
1.2.5. Ticks-Lyme community vector control (resistance, effectiveness)
1.2.5.1. Public conceptions (acceptance of AI).
1.2.5.2. ARS should demonstrate residential control reduces risk.
1.2.5.3. Rodent based treatment.
1.2.5.4. Specific acaricides,
1.2.5.5. Deer-based treatment.
1.2.5.6. ARS strengths, delivery systems, novel chemistries, working with partners (e.g. CDC in the case of Lyme disease).
1.2.5.7. Antibiotic prophylaxis.
1.2.6. *Amblyomma* (HME)-Lone Star Tick Control?
1.2.6.1. Systemics for treatment (deer).
1.2.6.2. Many of the tick control methods/tools the same as for Lyme disease.
1.2.7. *D. variablis* (RMSF)
1.2.7.1. Deer not important
1.2.7.2. Repellent-based treatment

1.3. New control against mosquitoes (*Ae. aegypti/ Ae. albopictus*) Urban
1.3.1. New screens to isolate potential biocontrol candidates. Formulations, how when, where to use these candidates.
1.3.2. Timing of treatments and when to use, how to combine.
1.3.3. Truck spraying not so useful against these species, have to use aerial. Have to know the population before you do any control. Thus, need traps-need to know what is out there.
1.3.4. Maintain efficacy of BTI by searching for recombinants.
1.3.5. ULV larvicides, combination usage. Some value into examination and getting into breeding sites.
1.3.6. Need more targeted integrated approach for control of container-breeding mosquitoes. Development of a potent ovitrap!
1.3.7. ARS demonstrate what are the appropriate tools and can they work-how to disseminate. Integration tools.
1.3.8. Development of this ovitrap will require further basic biology research on the attractants, repellents, and other behavior modifying chemicals, phagomones, etc.

1.4. Storm water management (retention ponds, underground catchment devices, etc.) present a special challenge nationwide. Develop solutions to these specific mosquito problems. Use engineering resources within ARS.

1.5. Bed bugs- General just kill them, discussed attractants yesterday.

1.6. *Cx. quinquefasciatus* and *Bacillus sphaericus*. Look for biological, sanitation, source reduction always before chemical treatment. Also requires resistance management when working with this species.
1.7. New personal protection techniques
    1.7.1. Non-destructive methods for clothing/military uniform. (Ticks, mosquitoes, sand flies).
    1.7.2. Portable detector of when to reapply repellent. (All species)
    1.7.3. Spatial repellent development.

Monitoring and Sustainability

1. Is a national program for monitoring insecticide resistance in public health pests needed?
    1.1. Mosquito-human contact intensity is usually much less than needed to sustain or drive a virus like dengue. What is the threshold?
    1.2. Spatial distributions.
2. What are early warning signs, very cheap surveillance, etc. that might warn of recurrence of a problem before it became economically damaging?
    2.1. We do not know the mosquito biting pressure in the U.S. (missing piece of data) that is essential to calculate risk models. Bloodmeal identifications does not tell us the whole story of biting pressure on humans.

Termites Breakout Sessions

Breakout Session I: Risk Assessment
Tuesday, October 30, 2007
1:20-3:15 PM
Facilitators: Frank Guillot & Alan Lax

- <u>What are the priority arthropod species affecting the commodity within the U.S.?</u>

  - Forest Service input would be valuable to address this issue
  - termites from elsewhere in world
  - ex. C. vastator and C. gestroi
  - drywood termites
  - Eastern subterranean termites, no idea of economic impact, need a figure

- <u>What are the priority arthropod species that might invade the U.S. and disrupt commodity production?</u>

  - C. vastator & C. gestroi in Palm Beach are beyond their point of invasion
  - new Coptotermes species from Taiwan
  - where are FST and where are they going
  - where do we look for them
  - movement into buildings, decommissioned rail lines
  - USDA can uniquely provide trained people who can look for termite infestations
  - no reason to assume termites in same genus will not behave similarly
  - those related to FST and EST may be on horizon of concern
  - knowing where termites are and proper identification are critical
  - molecular and taxonomic tools are essential
  - taxonomic ID requires expertise
  - list of species and where they may come from – is this a USDA issue

- <u>Is there a need for economic analysis of damage from any of these arthropods?</u>

  - Eastern subterranean termites, no idea of economic impact, need a figure
  - TAMU economists working on this in TX, will extrapolate data, focusing on counties with known infestation
  - look back over time at invasive changes vs. what is present now
  - most companies know the market is big enough, focus on purchased marketing studies published every 2 years, proprietary
  - non-biased study would be valuable for validation by comparison, but it must be updated regularly, ex. every 2 years
  - proprietary estimates do not include repair and damage
  - USDA is one of few agencies that could do independent study, would have to collaborate with sister agencies

- what do we know about economic impact
- we may be on front end of economic impact, urban ent may be predictive tool for a gent impact, may identify need to allocate resources to new areas or new insects
- may extrapolate to forestry industry, hardwood industry, small towns with hardwood forests, we will have the data when it happens
- trees of historic or aesthetic importance can be extremely valuable to the owner
- state-wide risk assessment will be different
- owner/neighbor disputes
- risk assessment – damage vs. can termite establish itself
- literature currently supports a $2 billion to $11 billion impact

- <u>What do we need to find out about these species in order to understand their potential for damage?</u>

  - commercial tool for potentially invasive species
  - quarantine rules currently exist, how can quarantine be made to work
  - how are termites transmitted along rail lines
  - who are we trying to educate: pest control, manufacturing industry, regulatory, homeowners
  - need successful quarantine program and successful education program
  - tied to sustainability and impact
  - education and regulatory issues related to storm debris removal
  - where termite is and stopping it from moving must be addressed as separate issues
  - sample data were not centralized so conclusions cannot be drawn
  - teach identification to Pest Control Technicians (PCTs)
  - print poster - call USDA if you find a suspicious sample
  - don't want deluge as happened to company that offered free treatment
  - research role – rapid or simple ID tools, development of molecular kits
  - National Pest Detection Network – what is major pest threat, who gets it for ID
  - what is role of USDA vs. APHIS or CSREES
  - TX PCOs know Reticulitermes vs. "something else", they often lump "something else" together as FST
  - baseball cards with termite stats for ID given to PCTs, kids, Girl Scouts, Boy Scouts, college service learning groups, kids will have pay attention to detail, parents may call in, easy dissemination of information
  - most important for PCT to bring suspicious sample to expert
  - how will PCT know how to get sample to expert
  - experts have to go out, not wait for samples to come in
  - PCTs see termites on a daily basis – give them mechanism to get ID done
  - will add to cost
  - NOMTCB gave post-paid packages for termite ID to PCTs and did not get strong response except when getting PCTs excited about the effort at recertification classes, etc.

- most practitioners in New Orleans are small companies, will not have time or staff to test samples
- how do we engage PCTs – they don't have time to be engaged, economic incentive to collect termites, economics will impact quality of what is collected, 800 phone number, websites, but are websites too numerous, PCTs will not go to websites but homeowners will
- is the greater risk what we know is present or what could potentially enter
- look in other countries where R. flavipes has established, adjusts to more climates
- FST, R. flavipes, and C. gestroi are top 3 invasive species, do they share niches
- why does Coptotermes outcompete – population in China is very dense
- research question to be answered
- FST infest forests in China but do not seem to threaten timber industry
- biological comparative research is needed
- why are FST not in sugar cane
- pesticide is put down when cane is planted, fire ant may have an impact, cane is recultivated every 3 years
- ornamental cane planted without pesticide will become infested
- pecan trees are being looked at in TX with concerns about the future, pecan trees are related to hickory trees with
- is federal collaborative research about invasive species being done before they come from another country, ex. Environmental conditions – being addressed by European and Australian labs, biocontrol in general, not just termites, not specifically looking at economics
- sampling – follow medical industry model, part of licensing requirement
- usually don't see termites on a termite treatment job
- state regulations vary
- at some levels treatment is not needed, PCTs just treat
- may result in a problem later if treatment stops working, lack of early ID led to establishment of FST in New Orleans

- <u>How can genomic studies be integrated into this topic?</u>

  - ID related to geographic distribution and reinfestation
  - submission to GenBank for exclusion of inappropriate markers and selection of ideal markers
  - recent manuscript validated evaluated markers
  - want baseline that can be used by someone without molecular expertise
  - relationship to know species on other continents
  - important to ID correct caste

<u>Summary</u>

- climate/temperature may limit spread of invasive termites in US
- need to ID potentially invasive species
- need to ID economic impact of invasive and potentially species
- survey and identification

o enlisting help of PCTs vs. experts going out
- education of public
o cards, posters, phone number, websites, variety of methods needed, must be repetitive, spokesperson would be valuable
o Co-Op extension service – collect samples, compile data, facilitate surveys
o USDA is logical clearinghouse for the effort

- <u>What are the gaps in our ability to detect and quantify priority arthropods?</u>

- survey and surveillance are different
o what has not been there before vs. looking again at what is known to be present
- how close is sound technology to being applied
o need for quick detection methods
o present methods are time and labor intensive
o state of the art is useful for research, will industry use it, why have they not
o industry will not invest thousands of dollars for a single tool
o cannot compromise on cost of accelerometer, other parts can be economized, tool could be cheaper if mass produced
o accelerometer good for spot checking, too slow for large scale
- conventional lasers not ideal for this application, outcompeted by sound technology
- infrared laser may be more compatible, 1550 nm laser makes the technology portable, photodetectors also useful for structures
- important to not become over-reliant on tools
- sound technology can be used by trained technologist to detect between FST and native subterranean termites
- level between detection and surveillance exists
o do not have improved tool to monitor termites in an area, still using bucket traps
o focus on sensing chemical/gas emissions from termites, proportions of those chemicals, don't solely rely on physical sensing, similar to radon exposure in homes
o look for less elaborate detection process, esp. in the soil
- how do we monitor population in a large area
o we may need 2 tools, not 1 tool to do 2 jobs
o camera detection
o spatial relationship of canopy cover and alate swarming should be investigated, remote sensing technology
o may not show exactly where alates are, but give an intelligent approach to their location
o will take intensive ground work, being addressed
o can detect sick tree, but is it sick from termite infestation
- NMR to ID change in components of wood when digested by termites
o can show that termites are present
- don't replace wood stakes but make them more attractive to termites so they will be hit more often
o may bias response, want to see termites respond in their natural state

- will need to monitor local gas emissions even in a large area
- no guarantee that outside monitors will detect activity near a known infested structure
  - will alone not be overcome by the sophistication of the technology
  - need presumptive survey with specific follow-up if suspect areas are found
  - this alone is a researchable issue
- basic unit is the colony, not the single termite
  - mark-release-recapture and genomics are currently used to quantify
  - genomics of alate catch homogeneity can be used to answer whether control is effective
  - will genomic ratios with multiple loci hold up at higher numbers of individuals, ex. 100, 1000 in same species
- when and how often are alates produced, developmental question
  - can artificially bias data by what is collected
  - facultative parthenogenesis occurs in Reticulitermes, not FST
  - can impact colony development, surveillance
- field studies needed for colony development, lab studies not effective for development of alates
- cannot perform surveillance on what you do not fully understand, need to find place in plan for USDA to conduct long-term, risky research
  - fundamental questions are critical
  - understanding of basic knowledge has impact also
  - what we develop has potential impact on other pest species
- need to conduct research in field areas that are not urban to count number of termites per colony
  - ties in to population management
  - if you kill colony what is subsequent scenario
  - Armstrong Park colonies are too small
- basic knowledge about developmental biology
- radio frequency ID chips that are the size of a grain of rice
  - no good antenna yet available
  - mark alates
  - marked termite would be killed by nestmates
  - stable radionuclear isotope cocktails in coyotes, cocktail unique to each coyote, radionuclear excretion was tracked
  - similar work done with ants
  - does not provide population estimate
- potential infestation from private ships is not inspected or detected by APHIS

- <u>Do we need any of the following for priority arthropods:</u>
  - New toxicants (and what kinds)

- goal in French Quarter (FQ) is population management, not just to protect structures
- Termidor is being used in second expansion area, was not available as a treatment when project first started

- o baits still predominate in FQ, not so nationally
- there is an information gap in comparison of chemical treatments available and their effect on populations
- structural protection is still important as demonstrated in the FQ
- barrier protection was based on protection from native termites which are desirable in a forest setting, is a different story with invasive termites such as FST
- untreated secondary structures on property are sources of re-infestation in FQ
- comparative studies of products are critical
- wing design – horizontal wood buried adjacent to or beneath bait station increases footprint of station and potential point of intercept
- investigate predicted pattern of termites tunnels for placement of bait station
- o extrapolate lab studies to the field
- in TX pre-treatment of wood with borate is allowed, does not address penetration issues
- o solubilization of insecticides to increase penetration into wood is known, but not longevity of the treatment once it is in the wood which is more stable than soil
- potential of natural volatile compounds as fumigants
- o valuable against drywoods
- o will be difficult to reach underground galleries
- o not residual in structures
- o natural products are difficult to commercialize
- control of alates alone will have only a minor impact on reinfestation
- o homeowner concerns about swarming alates can be allayed by direction to use pyrethroids to kill alates
- o issue of the colony that is producing the alates needs to be addressed by the homeowner
- o only approximately 1% of alates survive post-swarming
- why will termites avoid some bait-stations/wood and not others
- o heterogenous nature of soil composition plays a role
- o attractants in fungal-degraded wood
- o Odontotermes formosanus will not enter wood traps, used mushrooms for detection in China, mushrooms die when termite enters station
- o aggregational behavior may be involved, by it changes
- o much left to learn about pheromones
- o will bury unused tunnels
- o movement changes constantly, is a dynamic
- o aboveground dynamic is different, radiates less than underground
- o may be affected by gravity
- o definite researchable area
- o USDA uniquely capable of doing this
- phagostimulants
- o some data has been published
- o more work needed
- private sector is doing much work in this area
- o some patents are about to expire
- o resources invested in this area to release new chemicals

- USDA should not compete in the discovery of new chemicals
- USDA should investigate the behavioral/biological response of what is discovered
  - future development of product for use by property owners
- potential liability issues
- disclaimers do not absolve all liability
- education of property owners is necessary
- research what homeowners would do with a product, as opposed to development of an actual product
- property owners in FL had attention span of 9 months
- bias will be the fact that a homeowner willing to be monitored is not an average homeowner, and the act of being monitored is alone a sustainability motivator
- prior to French Quarter project 14% of homes had been independently treated, in expansion area it is approximately 75%, education has made the difference

- New biocontrol agents (and what kinds)

  - continue work in this area
  - hard to break FST defenses
  - delivery system work at USDA needs to continue
  - trees are known areas of infestation, known targets for treatment
  - mulch as biologically-based, cultural control
- FST tunnel through it
  - new media, such as foam, and strategies needed to increase virulence of entomopathogens
  - focus on microbial control, not biocontrol
- not likely to find other insects to control FST
  - will be hard to deliver enough microbes to overcome termite defenses
  - have focused on using soil pathogens to kill co-evolved soil insects
- use instead non-soil pathogens
  - research needed on biological substrates
  - Uzbekistan scientists have found microbes that are effective against termites from other insects
  - need to also investigate viruses
- area in which to integrate genomic studies
  - studies on birth control of termites would be long term and delivery would be difficult

- New cultural control technique

  - site management, eliminate conducive conditions
  - education component, interaction with property owners
  - pre-construction practices such as burial of wood need to be addressed

- New physical control techniques

  - Termimesh and Impasse are available but not being heavily used

- o distribution, manufacturing and cost issues
- o study economics of rebuilding in New Orleans area where many chose concrete, stucco, cinder block, stainless steel, etc.
- - sprayable plastic (Rhino truck bed lining) impregnated with pyrethroids is being used for control of other insects
- o has potential application here
- - model house with termite prevention mechanisms is available for view
- - property owners are not primary decision makers
- o education of builders is needed
- - building codes were changed in FL, but are not enforced
- - USDA can help change building practices of modular home builders in termite infested areas

- <u>What are early warning signs, very cheap surveillance, etc. that might warn of reoccurrence of a problem before it became economically damaging?</u>

- - education is primary
- - continuing control following the demonstration project
- - abatement districts
- - treatment model should be different from mosquitoes which know no boundaries due to their flight patterns

- <u>How can successful programs be made sustainable? Kept sustainable?</u>

- - involve industry in monitoring responsibility
- o USDA coordinate involvement of community associations
- o how to address communities without associations
- - demonstration project to dissemination information to help consumer decision making
- o possibly include consumer-applied product in the future
- o involve schools, extension services and PCOs
- o similar study was done in Golden Beach, FL
- o participation dropped over time, but did not involve school children
- o school education program succeeded in HI
- o use long-term pre-education format first for best chance of success
- o public confidence in treatment is reflected in increase in number of structures in FQ that were already treated in the expansion areas

Urban Entomology and Fire ants

Group:	**Fire ants**
Facilitator:	Dr. Robert Vander Meer

- **<u>What are the priority arthropod species affecting the commodity within the U.S.?</u>**
  RIFA (black/red/hybrid)
  Argentine ants *(Linepithema humile*) (present in US)
  Polistes (paper wasp) (present in US)
  Paratrechina pubins (crazy ant) (present in US)
  Little fire ant (*Wasmania*) (present in US)
  Vespula (present in US)
  Household ants (present in US)
  White-footed ant (not in continental US)
  Carpenter ants (present in US)
  Protection from exportation of RIFA to other countries in commodities.
  Brachymyrmex (black rover ant, first in FL in 1978) Found throughout SE US now. Low medical impact but high pest status).
  Pheidole obscura
  Pheidole megacephala
  Wasmania aeropunctata (Little fire ant)
  Anaplolepis (yellow crazy ants)
  Asian needle ant
  European fire ant
  Fleas
  Bed bugs (present in US)
  Cockroaches (present in US)

  Summary: RIFA, little fire ants, crazy ants, and argentine ants are considered the top concerns. Other ants were also identified. Non ant arthropods included fleas, cockroaches, and bed bugs.

- **<u>What are the priority arthropod species that might invade the U.S. and disrupt commodity production?</u>**
  Leaf cutter ants
  Other *Solenopsis* species

  Summary: Other *Solenopsis* species and leaf cutter ants were identified.

- **<u>Is there a need for economic analysis of damage from any of these arthropods?</u>**
  Wasmania (significant impact but limited to Hawaii)
  Examine what is known about species in other locations where they are invasive.
  Update economic impact of RIFA.
  APHIS quick economic assessment via literature.
  PCOs (often first access and observation of pest).
  More economic assessment of the yellow crazy ant.
  Platform model –scenarios in invasives.
  Conservation groups own assessment of impact in Hawaii.
  Economic Research Service, Lack of analysis for invasive ants potential collaboration
  PRIESM—funding program of ERS.

Summary: Yes. Little fire ant (medical quarantine and agricultural impact). Yellow crazy ant has potential to have large economic impact. Need for updated economic assessment of RIFA. And other ants with the potential to become invasive.

- **<u>What do we need to find out about these species in order to understand their potential for damage?</u>**
  Evaluate potential distributions via modeling (potential range).
  Damage in indigenous areas.
  Anecdotal reports of damage in indigenous areas.
  RIFA range expansion in the US—especially in light of global warming.
  BIFA range expansion or potential distribution.
  Basic information on biology (colony size, density colonies/area, dispersal potential, modes of dispersal).
  Rate of dispersal.
  Evaluation of control measures (specifically insecticides—type of insecticide availability is variable depending on quarantine).

Summary: Potential range. Damage caused in indigenous areas. Basic information on biology (colony size, density colonies/area, dispersal potential, modes of dispersal).
Rate of dispersal. Evaluation of controls.

- **<u>What tools would be useful for risk assessment of these species?</u>**
  APHIS has guidelines in place for risk assessment, but information is not always available.
  Baits for detection.
  Voucher specimens.
  Specimens from other countries.

Summary: APHIS has guidelines in place for risk assessment, but information is not always available. Baits for detection. ARS foreign labs may provide information on risk assessment (vouchers, DNA source, etc.).

- **<u>How can genomic studies be integrated into this topic?</u>**
  Identification verification of species.
  Source location.
  Quick tests for determining identification of species.
  Field tests.
  NMR with magnetic beads based on existing genomic information.

Rapid screening from WMD technology.
Homeland security collaborations (3D comparison).
Haplotype assessment (number of introductions).
Determination of origin of introduction (based on genetic data from indigenous regions).

Summary: Identification verification of species. Source location. Quick tests for determining identification of species. Field tests. NMR with magnetic beads based on existing genomic information. Rapid screening from WMD technology. Homeland security collaborations (3D comparison). Haplotype assessment (number of introductions). Determination of origin of introduction (based on genetic data from indigenous regions).

Open questions:

1. Using contacts within ARS in other countries (e.g. Argentina) to gain risk assessment data *a priori*. Utilize ARS labs in other countries.
2. More interaction with Pacific ant program.
3. Do we have a good voucher specimen collection in the USDA.

- **What are the gaps in our ability to detect and quantify priority arthropods?**
  Delivery systems—sustained released or presentation for target species.
  Food baits not sufficient to detect invasives.
  Specific attractants for invasive species.
  Lure development.
  Flushing agents (especially for shipping agents).
  Ant odor detection.
  Be alert to utilization of new technology for detection of fire ant odors.
  Prioritize commodity evaluation.
  Develop contamination likelihood of exports to harbor invasive species.
  Shipping and tracking coordination.
  Resources (staffing/funding).
  Enhance interaction with homeland security to aid USDAs detection of invasive species.

- **What are the gaps in our ability to detect pathogens transmitted by priority arthropods?**

- **Are there products already invented that need to be transferred to industry or other user groups?**
  Remote sensing (expensive but effective 80%)
  Solenopsis specific attractant.
  Cost too high for area-wide control, especially in agricultural settings.
  Bait with lure for fire ants is under patent review.
  Tools to differentiate RIFA from BIFA and Native fire ants.
  Sustained delivery system which may be available from existing sources.
  Non-repellent insecticide.

- **How can we improve surveillance systems for potentially invasive species?**
  RIFA—educate doctors to recognize fire ant stings.
  Educate groups for detection of invasive species (extension agents, students, public, etc.).
  Lures/traps/protocols for detection of ants other that RIFA.

Survey technique sensitivity (for example, to label an area free of fire ants—deregulated).
Develop new sensitive survey techniques.
Utilize landscape metrics for surveying ants.

- **<u>How can genomic studies be integrated into this topic?</u>**
  Identification confirmation and origination determination of invasive ants.

- **<u>Do we need any of the following for priority arthropods:</u>**
  - New toxicants (and what kinds)
    Delivery systems are needed to get the toxicant to the ants.
    Cost is an issue for producers—lower cost for application over wide areas.
    Integrate toxicant with fertilizer or another product to reduce costs.
    Longevity should be increased to make it last longer.
    Don't necessarily need more active ingredients, however, we do need a cheaper bait system.
    Controlling queens, entire colony structure.
    Formulation chemistry should be addressed to improve efficacy of mixing insecticides and other chemicals like fertilizer.
    Sensor production that can detect mounds and apply baits in a targeted method.
    Need new toxicants because some have failed to work.
    Need new toxicants for other invasive ants or determine efficacy of existing active ingredients on these other ant species.
    Other formulations for other applications like arboreal (perhaps a paste).
    Stability of baits in humid and wet conditions.
    More toxicants for use in broad spectrum applications for ants.
    Need to replace bifenthrin for use in meeting quarantine restrictions in California.
    Argentine ant: need formulations and toxicants for use against these ants.
    Organic growers are being ignored—what can be provided to these growers for ant control.
    Texas—*Paratrechina pubens* need a management strategy and toxicants/formulations that are effective against this ant (crazy ant).
    Hawaii—*Wasmania*, need baits that are effective in humid conditions and in formulation to treat arboreal ants.
    Develop an IGR system for argentine ants.
    Older active ingredients are beginning to show up in water systems—need new active ingredients to replace these compounds.
    Develop methods to protect shipments from ants—treat in containers or transporters.

  - New biocontrol agents (and what kinds)
    New biocontrol agents to help reduce costs of control.
    Look for more biocontrol agents in native region (critical for little fire ant and RIFA).
    Fungal pathogens for microbial control.
    Bacteria and fungi for microbial control.
    Livestock point of view—augmentation of non-sustainable control agents.
    Biocontrol research for other invasive ants sorely needed.

- New cultural control technique
  - Develop a transgenic plant or grass with ant killing transgenes.
  - Endophyte effects on fire ants.
  - Trap cropping for organic farming situations.
  - Mulching to prevent foraging.
  - Mulch augmentation with insecticide for control.

- New physical control techniques
  - Barriers or exclusion devices.
  - Barriers for well pumps and other electrical devices.
  - Barriers for nursing home protection.
  - Fertilizer/anydrous ammonia

- **How can we integrate control techniques? (To avoid interference with process, to minimize cost, to leverage effects of one life stage on another, to enhance safety, etc.)**
  Compatability of chemicals and biological agents.
  Develop a management technique that is cost effective.
  Integrate controls with surveillance.
  Co-application of insecticides and fertilizers.
  Combination of active ingredients with different modes of action.

- **How can genomic studies be integrated into this topic?**
  Finding parasites/pathogens in native region.
  Strain characterization and ID pathogens.
  Confirming where the ants come from.
  Functional genomics to identify and exploit vulnerable genes (e.g., RNAi).
  To determine the responses of pathogens and parasites.

- **What are early warning signs, very cheap surveillance, etc. that might warn of reoccurrence of a problem before it became economically damaging?**
  Community wide control of fire ants.
  Monitoring reinfestation.
  Sustainability and economic threshold determination for different situations.
  Ports of entry monitoring system for invasive ants.
  Cactus moth surveillance method as a good example to follow for ants (e.g., master gardeners etc.).
  Monitoring network comprised of numerous individuals to determine reinfestations and monitor the leading edge of infestations.
  National plant diagnostic network (NPDN) is an excellent example to follow.
  Spatial analysis.

- **How can successful programs be made sustainable? Kept sustainable?**
  Funding and public relations need to be maintained for a diagnostic network to be effective.
  Surveillance networks would trigger follow-up treatments.
  Area-wide project and maintain funding for successfully transferred technology from states to the USDA.

Economic analysis after treatment.
Monitor biocontrol agents after release to verify its presence over time.
How will homeowners sustain RIFA control (refer back to community-wide control of fire ants).

- **How can genomic studies be integrated into this topic?**
  Identification
  Determining the origin of introduction (from introduced and native ranges).
  GIS integrated with genomics methods.

Veterinary Entomology

Facilitator: John George, ARS, Kerrville, TX
Recorder: Kim Lohmeyer, ARS, Kerrville, TX

- **<u>What are the priority arthropod species affecting the commodity within the U.S.?</u>**

1) Stable flies*
2) Screwworm*
3) Horn flies
4) House flies*
5) Face flies*
6) Mosquitoes
7) Tropical Bont Ticks
8) Cattle Lice* - resistance to current products
9) Culicoides spp./Black Flies* as vectors of arboviruses/EHDV
10) Cattle Fever Ticks*
11) Heel Flies
12) Black legged ticks
13) Face flies
14) Dermacentor andersoni
15) Litter beetles
16) Mites
17) Lone star ticks
18) Ornithodoros spp.
19) American dog tick
20) Northern Fowl Mites

* Denotes priority

- **<u>What are the priority arthropod species that might invade the U.S. and disrupt commodity production?</u>**

1) Screwworm
2) Tropical Bont Tick
3) Cattle Fever Tick
4) Old World Screwworm
5) Stomoxys nigra
6) Container breeding mosquitoes
7) Container breeding insects (ex: Culicoides)

- **<u>Is there a need for economic analysis of damage from any of these arthropods?</u>**

1) Mosquitoes – on cattle, swine hide damage, horses (activity such as tail swishing)
2) Flies – large facilities, image/perception by public, zero tolerance, sociological issues
3) EHDV vectors – spillover into cattle from deer
4) Stable flies – Pastured cattle
5) House flies/stable flies – swine
6) Tolerance levels have changed – less tolerant to flies on pets, in homes, etc.

7) Public health issues need to be factored into economic damage assessments; Ecoli/salmonella transmission associated with large production facilities

- **<u>What do we need to find out about these species in order to understand their potential for damage?</u>**

1) Cost to control
2) Vector competency ex: EHDV
3) Risk assessment maps for introduced species ex: Old World Screwworm
4) Model climate/seasonality – regional differences and impact of climate changes
5) Reanalyze for current distribution
6) Impact of seasonal migration (stable flies and house flies)

- **<u>What tools would be useful for risk assessment of these species?</u>**

1) Surveillance
2) Prediction models for changing climate - West Nile, EHDV
3) Habitat and potential risk analysis using GIS and satellite imagery analysis
4) Models that include management options and technology transfer. Why do the work if no one gets the information?
5) Field ID technology for EHDV and other viruses

- **<u>How can genomic studies be integrated into this topic?</u>**

1) Genetic identity of migrating stable flies
2) Insecticide resistance tools/mechanisms
3) Producers see genomics as a lower priority – producers would like to know about what can be done now
4) Gene flow – genetic markers that go with vector groups – help with tracking disease transmission
5) Host genetic differentiation – host pathogen interaction ex: Why are certain populations of white-tailed deer resistant to EHDV and others are not?
6) Diagnostic tools (markers) for potentially invasive species such as African *Musca* or *Stomoxys*
7) NRI priority

Surveillance

- **<u>What are the gaps in our ability to detect and quantify priority arthropods?</u>**

1) Ability to identify and detect priority arthropods; med/vet courses and basic taxonomy are
lacking; these positions are becoming fewer and fewer at universities; Who is currently trained to identify new invasive species?
2) Ports of entry detection? (Ex: Ticks on reptiles, amphibians, snakes).
3) Strengthen skills of extension entomologists – is this a job for ARS or the universities?
4) System support of the above - is this a job for ARS?

5) Sampling, trap design

- **<u>What are the gaps in our ability to detect pathogens transmitted by priority arthropods?</u>**

  1) We lack accurate and timely detection methods for pathogens transmitted by arthropods.
  2) Existing technology for detection has not been transferred or made cost effective. On the other hand, what is the demand for these assays outside ARS? What pathogen analysis kits are a priority?
  3) Tools to identify exotic viruses coming in to the country. Tools aren't rapid.
  4) Need for a group of rapid diagnostic tools for common disease agents; getting tools to the practicioners; Facilitate licensing of ARS patented ID tools.

- **<u>Are there products already invented that need to be transferred to industry or other user groups?</u>**

  1) Rapid pathogen diagnostic tools

- **<u>How can we improve surveillance systems for potentially invasive species?</u>**

  1) We need a list of high priority potentially invasive species for a port of entry "watch list"; back of APHIS.
  2) Surveillance of wildlife as disease vectors
  3) Tools for Blue Tongue virus detection.

- **<u>How can genomic studies be integrated into this topic?</u>**

  1) Discussed in previous breakout discussion.

Control

******Critical Need for Livestock/Vet Entomology positions and extension positions at universities*******

- **<u>Do we need any of the following for priority arthropods:</u>**
  - New toxicants (and what kinds)
    1) Continuing need for new insecticides due to loss of products and/or resistance, stable but environmentally friendly
    2) Pyrethroid resistance – need alternatives for fly control, winter tick
    3) Need for control measures for organic market
    4) Need for alternatives that are stable in larval habitats
    5) Repellents for livestock – needs to be explored
    6) Better management of the insecticides we do have
    7) Look at natural products developed for plant pathology as potential arthropods repellents
    8) "Home remedies" such as garlic should be investigated. Do they work?
    9) Producer comment – repellents would be at the bottom of the list – Need to kill in the larval stage before there is a problem

- New biocontrol agents (and what kinds)

    1) Interest as long as there is not a non-target effect. Are they really successful in the pasture setting?
    2) Climate issues, movement of parasitoids needs to be investigated
    3) Parasitoids could be a part of an integrated management program
    4) Fungi candidates need to be further investigated and/or formulated for field use
    5) Pathogens, parasitoids, fungi, etc. are needed but they need to be low labor, economical, effective against larval, stable, etc.

- New cultural control technique

    1) Sanitation is key
    2) Breeding site management, especially for stable flies
    3) Basic biology for stable flies is needed, all breeding sites, range, life history are still relatively unknown
    4) Area wide management – some concern that producers will not participate
    5) *Culicoides* breeding site management; also need basic biology studies
    6) Need physical markers for population identification

- New physical control techniques

    1) New research on trapping and attractants to put in traps and/or with toxicants; traps that are user friendly and low maintenance. Needed for mosquitoes, stable flies, house flies, *Culicoides* "Lure and Kill"
    2) Better facility management and/or facility construction
    3) Barriers, habitat corridors need to be looked at
    4) Again, basic biology is needed

- **How can we integrate control techniques? (To avoid interference with process, to minimize cost, to leverage effects of one life stage on another, to enhance safety, etc.)**

    1) Integrated control is definitely needed.
    2) On farm demonstrations are of interest.
    3) Need for economic analysis for integrated control
    4) Is the integrated system "Operationally feasible"

- **How can genomic studies be integrated into this topic?**

    1) Tracking of "moving" populations. Use genomics to determine if movement is happening.

Monitoring and Sustainability

- **How can successful programs be made sustainable? Kept sustainable?**

1) Extension positions – we are losing these
2) Teaching positions – not being filled
3) Outreach component for ARS? – we need to sell ourselves better, the public has no real concept of the threats we address

Sensory Ecology Group 1

Sensory Ecology III Chemicals Affecting Hematophagous Arthropod Behavior/Sensory Ecology Part 1 – Allan - Facilitator

1. What are the basic research questions that will lead to valuable applications?

How important are new attractants?

Need as related to specific behavior? Related to improving trapping. Could be used to improve insecticide control by exposing the pest (move from hiding areas).

What are carbohydrate sources for biting insects?

2. What should be our model organisms?

Honey bees
Aedes albopictus
Culex pipiens complex
Stomoxys calcitrans
Ixodes scapularius
Cattle fever tick
Lone Star Tick – Diseases associated

3. How do we prioritize behaviors to affect or test?

Host Seeking
Oviposition
Carbohydrate sources (energy) selection, surveillence
Resting Sites
Feeding Stimulants (cues) associated with specific feeding behavior
Flight
Mating behavior
Larval- feeding, aggregation (directed toward control)
Priority depends on the situational target

4. How do we develop the best and most appropriate bioassays?

Identify the system and then the bioassay is developed (system, behavior and species driven)
Must be validated by others (researchers).

5. Should we be screening chemical libraries? What is the best way to prioritize chemicals?

Develop an algorithm between cost and efficacy.
Livestock is a small market for such chemicals (compared to crops) ARS may need to pickup this void to demonstrate

Repellents
Attractants (attract and kill)

6. How does electrophysiology fit into this research area?

Used in conjunction with screening
Electroantennograms- antennae are affected when a volatile chemical comes in contact.
Response is electrical. Does not determine attractant/repellant
Linked to gas chromatograph to identify compounds for a mixture to determine what activates the sensory cells.
Response to specific chemicals. Can be used to identify specific sensillae.
Used to screen chemical compounds (ie toxicants)
Tick feeding affected by chemicals in the blood
Can be used for all groups of insects of interest.

7. How does biochemistry (receptor proteins, etc.) fit into this research area?

8. How does genomics fit into this research area?

Identify the proteins involved in sensory activation. Determine the mode of action of a chemical. Aid in identifying chemical with similar affects.
Chemicals could possibly be developed as blocking agents for binding sites.

Part 1:

1) Intersection between this field and solution of practical problems?

Covered in the first group of questions
Larval trapping for biting Diptera (*Culicoides, Culex, Aedes*)
Tools are needed for specific species.
Combine visual cues and chemical (olfactory) attractants (cues) for trapping
Trap evaluation

2) How can we facilitate transition of products to market

SBIR programs phase 1 and phase 2 funding. Preliminary research.
Development of new products.
Technology Transfer Centers

Host Finding -surveillence, control, research, olfactory cues
Carbohydrate selection- used for toxicant delivery, improved baits, associated olfactory cues.
Oviposition- identify targets to direct control against larvae, surveillance tool, colonization tools, oviposition traps with lures, olfactory cues, improved surveillance for viruses

Resting site selection- blood meal analysis, push-pull, improved surveillance for pathogens, overwintering ecosystem

Feeding cues – (what causes the probing to obtain a blood meal) disrupt feeding, toxicant uptake, interaction of behavioral factors,
Targeted biting sites, feeding cue changes with different life stages (ticks),

Flight cues- activate to bring to open to expose to toxicants, especially useful for arthropods that rest in hidden sites (ticks in grass)

Mating- sterile release, mating disruption, transmission of insect pathogens (std)

Larval Feeding- toxicant delivery, biocontrol agent delivery, enhance food intake (Hyperphagia) to reduce rate of toxicant needed

Larval aggrevation- trapping, sampling, control, enhanced biocontrol (predators and parasites)

1) How can ARS become a center of activity?
   Collaboration of clear goals (areas of major importance) Stakeholder driven (identify problem), scientist driven (develop solutions).
   Policy directed by administers
   Interlaboratory interactions, Virtual laboratory?
   Chemical ecologist are commodity directed.
   Scientist must be willing to work with the “system” in order for a virtual laboratory to work. (People who seek for cooperation).

Sensory Ecology – Group 2

Discussion: Chemicals Affecting Hematophagous Arthropod Behavior/Sensory Ecology, part 1,Colorado 1

1:30-4:30 PM, Wednesday, October 31, 2007 (Break at 3:00 pm)

Group:	**Sensory Ecology I**
Facilitator:	Uli Bernier
Recorder:	Jerry Hogsette
Presenter:	Roger Nasci

1. What are the basic research questions that will lead to valuable applications? As recommended in the evaluation of the NP104 report, a sensory physiologist is needed to enhance the pipeline for product development. Areas mentioned were trap improvement and repellents.

2. What should be the model/target organisms – most work done previously on mosquitoes and ticks. Could the work being done on bee sensory ecology be applicable to arthropods of medical and veterinary importance? Target species should be the one most affecting the general population. Targets could be any organism for which attractants and traps are needed.

2.1. Prioritization of these within ARS should be the first step.
2.2. Mosquitoes – *Aedes aegypti* in particular, sand flies, stable flies, ticks (specific species targeted as priorities, *Ixodes, Amblyomma, Dermacentor variablis*), Bed bugs, fleas, black flies, house flies, screwworm flies. Anything but lice.
2.3. Stakeholders are not as familiar with this field. Perhaps even add *Cx. pipiens* complex, *Ix. pacificus* along with *Ix. scapularis*. The driving force should be product development, such as one to prevent tick bites, or an anti-questing chemical. Better surveillance and control for urban mosquitoes. Unique container mosquitoes.
2.4. …and don't forget to continue repellents research!
2.5. Organisms that threaten our well being: mosquitoes, bed bugs, fleas, ticks.
2.6. ARS should perform the leading role in determining compounds to test further.
2.7. All but lice could benefit with regard to trap research: traps, surveillance and pheromones. Work with those species ARS is charged with.

3. (How) do we prioritize the behaviors to test? Depends on the desired use of the end product, e.g. oviposition attractant, feeding stimulus.

3.1. These will lead to better tools to evaluate risk. Need standardized set of tools to use for testing. Two responses: attractant or repellent.. ARS needs to work on both kairomones and allomones.
3.2. Choose kairomones for trapping. Repellents for DWFP.
3.3. A blood meal deferred by a repellent is almost as good as insecticide kill in a recent study with malaria transmission in Tanzania.
3.4. Coverage of product efficacy is important with respect to host and to other pest species.
3.5. Understand underlying activity (physiologically) associated with response to a chemical. Masking mixtures should be identified and evaluated.

3.6. Do insecticide resistance mechanisms have a part in this focus area? Critical for insecticide work. Screening for insecticide resistance is very important. Also, important not to reject a compound as unimportant just because it is not providing a signal in one assay method (e.g. no EAD signal).

4. How do we develop appropriate (best) bioassays?

4.1. Need standard evaluation protocol. Set up paradigm (standards/measures) to compare compounds within the same system.
4.2. Recommendations can thus be made, but could be modified if necessary.

5. Should we screen chemical libraries?
5.1. Yes. This is of definite use.
5.2. What is the level of candidate material to test. Depends on type of reaction to chemical (insecticide, repellent, etc.).
5.3. Also should there be a change as to what kind of compounds should be tested? Product/target profile is important. Preference of stakeholders is important. E.g., product to prevent ticks from invading neighborhoods or protect the inhabitants (repellents).
5.4. Military perspective-this is very important, as was the Gates Foundation perspective (cutting edge research).
5.5. In essence, want ARS to produce new products with both toxic and repellent effects.

6. How does chemistry fit into this area?
6.1. Volatiles that activate receptors and elicit attraction are needed, especially as a substitute for CO_2 - something that works just as well.

6.2. Which hosts do we study for kairomones (odor cues)?-Deers, humans, organisms as applicable to the charge of ARS.

6.3. Which plant(s) volatiles? (Scope/breadth)? Yes, since so many adults are nectar feeders, again may replace carbon dioxide dependence.

6.4. Role of computer modeling methods, e.g. QSAR? As demonstrated in literature, there is applicability of this area to the problem(s).

7. How do we integrate classic behavioral studies?
7.1. Determination of structure required to add candidate chemicals into the environment and have them function.
7.2. Important to take into account multiple cues, e.g. vision in addition to chemical detection.
7.3. These studies are the bridge to each of the other disciplines involved in sensory ecology. It’s a continuum-can’t understand complex behavior.
7.4. Studies to answer why chemicals either work or may fail in the field in the scale-up process from laboratory to field.

8. How does electrophysiology fit in this focus?
8.1. Primary screen to see if there is a response.
8.2. Subject chemicals that elicit a response to secondary test to qualify the response because it is limited to neural response.

8.3. Should this discipline be the central research area with a heavy thrust to understand sensory ecology? This work needs to be done in parallel, but is still important.

8.4. How widespread is this expertise? If expertise not readily available, may need to collaborate across units, areas, or outside ARS to have the necessary collaboration.

9. How does insect physiology/molecular biology fit?

9.1. Is there a value to odor-binding protein/receptor protein work? High throughput screening available as demonstrated by current cutting edge research projects.

10. How does molecular biology/genomics fit into this focus area? Yes, but ARS should not get into the sequencing business. Perhaps through EST library based on *Ae. aegypti* work for *Ae. albopictus* (to get the OBPs and ORs). Also, remember ticks, *Boophilus* and *Ix. scapularis*.

11. Can this research be done outside/external to ARS, e.g. by academia? Is it high-risk long-term research that should be a (continued) focus of a Federal Govt (USDA ARS) research program?

11.1. Yes, if the expertise is there, why not? This problem not being addressed by other agencies.

11.2. Ambitious project, ARS may need to prioritize.

11.3. Investing in well thought out basic areas (like this) is important.

12. Does ARS have the expertise to function well in this area? Yes. Vested interest.

12.1. Any critical deficiencies? Electrophysiology expertise and it is important to minimize deficiencies.

12.2. Strengths? ARS has a head start in this area and has already invested resources and shown progress and promise.

12.3. How does ARS integrate efforts across laboratories? Related to minimization of deficiencies.

12.4. Should this focus area (Sensory Ecololgy) be a separate CRIS project, or multiple CRIS projects. Should this work be integrated into Med Ent and Livestock Ent focus areas? As long as results are getting accomplished, this is not important to the stakeholders. No preference. Make it important to the agency so the money and support continue.

12.5. Can this focus become a nationally/internationally recognized “center” of activity in this field? Yes! With the right people, right products, good support, etc. Key is sustained commitment and ARS has a track record of this in the long-term investment in this area. Make this area important so that the agency (ARS) understands the value of research in this area.

13. How can we improve our efforts to commercialize products or transfer technology to our partners who are interested in our research?

13.1. Is this area attractive to our commercial partners to join in and collaborate in this endeavor? Yes, especially if there is commercial value in the products. Important to get private industry interested in what is being done over long periods so that they also have a vested interest in the success of the program.

13.2. Are potential results from this research focus useful to our (Federal) partners and stakeholders? Yes. Systems in place to help with patenting, licensing, and development are appealing to our academic partners.

14. How can we work within this field and leave flexibility to answer questions that we have not asked yet? In other words, how far outside this field should we pursue interesting leads? Should we bridge to other insects, perhaps not of medical and veterinary importance? Imaginative qualities can wane at the bench on occasion. There can be discoveries that are published but there is no continuation towards a commercial product. Orthogonal views and views from scientists outside of the field can be important. Ants and termites should be included in the electrophysiology group since many of the principles already discussed are pertinent to these groups as well.

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