Design of a Lepidopteran Aerobiology Modeling System

Minutes –by J. Golod, edited by S. Fleischer

Attendance: see Appendix I
Planned Agenda: see Appendix II

June 28th

Began 9:00 am with an introduction by Shelby Fleischer.
We are a highly interdisciplinary group from different institutions, private, public, and international, with large variation in areas of interest. What unites us?: applied ecology, pest management, and scale. Our work considers management and ecology of migratory lepidopterans at scales that must encompass migratory components of their behavior. New technologies and nascent institutional infrastructures increase our ability to do so. Science status updates this morning, then draft a Lepidoptera modeling system this afternoon.

Attendees with brief introductions: See Appendix I

Scott Isard- PIPE introduction
Isard discussed how the PIPE system came about. One aspect was the focus of ZedX Inc to weather data and web based application for agriculture pest management, which included quality control.

The other push came from USDA, started with NCERA148 committee and expanded from there. Had a workshop out of which came out the idea of monitoring and movement at a continental scale. Russo and Isard wanted to operationalize this concept and this was at about the same time that SBR came unto the scene. An SBR coordinated framework was formed. Soybean rust was found in early Nov 2004 in US. To address this new threat a soybean rust information system was developed utilizing an extensive monitoring effort with IT tools and modeling. The first year the pathogen didn't spread. ERS did an analysis and concluded that the system saved growers million of dollars. Given the success of the system, Isard proposed the PIPE framework and expanded the SBR framework to other pest. The fundamental aspect of this approach is people linked with the help of IT framework. Another key element of the system was risk management potential, and that is where RMA came in. The PIPE system currently includes soybean aphid and viruses of legumes, in addition to rust. The structure now has a steering committee with a broad cross agency and internal participation.
Scott showed and explained the PIPE diagram. Some key points: Modeling can occur in various institutions. There is an interface that allows a state specialist to communicate to their constituents.

Fleischer
Prior to 2000, regional monitoring focused on taking black light or pheromone data and putting it on web and showing spatial and temporal components. In 2002-05 had a grant that dealt with sweet corn and had five components. It advanced coordinated system of monitoring in NE, now known as Pestwatch (www.pestwatch.psu.edu) .

The NorthCentral IPM grant under which operating now, involves coordinated information flow from North Central region and merging information from North East- get a view of earworm north of migratory range. Bill Hutchison is the lead which is due to expire next year. Other relevant grants have been rejected. PIPE had a call for concept notes and Fleisher put in a brief five page concept note (which was distributed during the meeting). If something comes from the concept notes, there will be a call for proposals. Some of the institutional ways that a PIPE for migratory Lepidoptera could work are similar to what is being done with legume PIPE.

John Ayers

A PIPE steering committee was formed last year because the group realized that there was a need for a more structure and centralized way to oversee the system. There was a line item in the 2007 budget for soybean rust and RMA was interested in putting funds into PIPE, and there was discussion of expanding the PIPE to other host/pest combinations. Committee has a lot of representation: grower representatives, industry, CCAs, land grant universities, extension entomologist and pathologist, experiment station, extension committee, university administration, national plant board, NPDN, IPM centers, various agencies of the USDA, NRCS, RMA

Meet in face to face meetings a couple of times a year and hold regular, monthly conference calls. RMA put in $3.5 million and went through CSREES to move money out to states. FY07 did not receive the 2.4 million for rust as part of a line item, didn't make it in the final budget, but it's back in there now and there is strong support for it. RMA looks to have $5 mil to put into the PIPE system this year; after CSREES takes overhead will have about $4.5 mil, plus potentially the line item funds. The RMA funds would be used to expand the PIPE and that's where the call for concept notes came in.

Maybe about 22 concept notes were received (just a guess on the number). This year assuming the RMA and line funds are both approved, then will expand the IPM PIPE system on a competitive basis; if not, the system will not expand. Money flow in 2008 will be RMA-CSREES- NCIPM. John will be the grant manager for the system. About a million to be available for competitive grants- a panel will be convened to decide which projects will be funded. 10% overhead on those funds. NC regional responsible for the educational items. URL for the steering committee is www.ipmpipe.org

A question arose as to what alternative systems to SBR model can be used. Ayers said that alternative systems will be considered, but without discarding the system that has been developed. RMA is interested in insurance aspect, as this is their focus. RMA can only support expansion and development and not maintenance. If SBR line item is not approved in 2008, RMA did indicate that they will figure out how to expand soybean PIPE to keep it going. Down the road will need other funding sources to support the IPM PIPE system. There was a question about focus on minor crops by RMA. Ayers said that minor crops were discussed by steering cm, but no more or less than major crops.

Bob Seem mentioned that another potential funding source this group can consider is the ARS area wide management program.

Science Update

Monitoring at semi-continental scale Fleischer

Pheromone baited traps were monitoring migratory leps for a long time (> ¼ century) with diverse programs. If data are coming through a central system, can look at spatial and temporal implications of the data. Did whatever was needed to move data into central system. The data was diverse, some coming from individual faculty members and others through IPM; some cooperators were using black light and some pheromone traps, and different ones at that. For example, Maryland supplies growers with mailing tubes which are sent Annapolis where samples are identified and counted, and has been doing that over 30 years. This results in highly variable trapping systems. By 2002 were making clickable maps through Pestwatch, used early warning system and created confidence in what was occurring locally, and that changed the information flow dynamics. Example, contrast 2002, drought year, with much earlier migration processes than in 2005.

Geo-expansion of pest watch- merging of various data systems- second year NC IPM grant. Database aspect is working for this expanded system and visualization will be working in several days. Initially just compiling and visualizing data, but now need to work on more standardization in data collection and quality. In the SBR PIPE system, there was time and funding to develop standardized sampling protocols. In the Lepidoptera system there are issues of different collection techniques (blacklight, Hartstack traps – 4 systems in place in Pestwatch now), and there are reasons for the different regions utilizing different methods. There is also a difference in spatial resolution, the NE wants lots of data with local resolution, better than in NC. Conversely, temporal resolution is different as well, daily in NC vs weekly in NE.

Standardization of protocols needs to be a participatory process. An approach could be a small set of sites with first tier data quality, and around that a second and third tier data quality sites. For the last two year the goal was also to standardize the trap system. Bill Hutchsion mentioned that Hartstack traps are first choice based on the data thus far in the NC. Prefer the 75 cm, although harder to ship because of the size. Some prefer light traps because they allow for female catches. This is also an opportunity to use integration of hypothesis to gather better data. Phenology information is already available through ZedX. Monitoring on a semi-continental scale is starting, but the challenge is to do it well.

Pyrethroid resistance Hutchison

Insecticide Resistance Action Committee (IRAC) www.irac-online.org - interested in this project and helped with the funding for this meeting.

NA Zea Resistance Mapping and Management Network received both university and industry funding. Focus was to continue to build this network through NC and use more standardized protocols. Hartstack traps allow monitoring catches even at low level, Scentry traps have tendency to miss that. Also, facilitates catching more moths through high flights and thus more available to test for resistance. In terms of C3/C4 markers, grass and non-grass hosts, can help with that as well. Moving more and more towards real-time, checking

traps daily or several times a week. During the second year hope to have more education material.
Last summer set up simple website (see www.vegedge.umn.edu/ZeaMap/zeamap.htm). It has links to migration effort at NIU, Pestwatch, and provides pyrethroid resistance monitoring results. Forecast working well for NC region.
Roger Leonard pyrethroid resistance data shows increase in resistance, and once there is a "jump", it doesn't go down. Selection pressure in south contributing to it. In the late 90s, didn't get the expected 99% control; the application timing is critical. Beginning in 2000, went down to as low as 17% in 2001. In 2006 trial, for standard field rate, 55 -66% control. Have a new insecticide that is showing control, different mode of action than pyrethroid. At the end of season collect larvae and conduct adult vial test (AVT) bioassays, and F1 or F2 larval assays from samples sent to LSU; larval assays with cypermethrin resistance ratios of 6 to 8, suggest concern as over 5. More recent lambda cyhalothrin getting even higher resistance ratio on the larvae.

Resistance Monitoring- standard –These results don't have major resistance issues, but larvae with AVTs get very high percent survival.

North Central Branch symposium convened and symposium proceedings due out soon, on-line, in Plant Health Progress.

Summary:
Within a colony (R.Leonard)
- some show average resistance
- some high susceptibility
- some express very high resistance

There are some concerns about AVTs from field-collected adults from pheromone traps, versus AVTs from adults reared from field-collected larvae. Field AVT (low resistance) vs poor field control, maybe false negative for high value crops.

Graduate student at Purdue looking at mechanism of resistance. Fleischer indicated that Dr. Pietrantonio's work, due out soon, suggests problems in Texas attributable to a single allele.

Defining host sources **Head**
Looking at different techniques to examined larval host plant chemistry which is reflected in the composition of adult insects.
One approach is carbon isotope analysis, C13/C12. The ratio is different for C3 and C4 plants. Based on the five (southern) states examined and focusing on the corn earworm earlier in the year there is a mix of C3/C4, mid season almost entirely C4, and later in the year again a mix. One assumption is that crops immediately surrounding traps had no impact on c3/c4 derived insects. And across state level the broad patterns are very similar. Early on non-cotton c3 alternate hosts, mid c4 alternate hosts, and late cotton is an alternate host. Made sure that gossypol signal only came from cotton and used those methods to measure those who fed on cotton. Up to 20% common from cotton. Something other than

cotton is contributing in some states and not others. Combining these techniques can help to identify where insects are coming from and compare to cropping patterns.
Used the nicotine technique to identify which came from cotton or tobacco. The theory is that they can't come from both because larvae do not move that much.
The conclusions were that that these techniques are sensitive as long as targets are appropriate, that methods work in all species tested, and can often be combined, and that results can be compared to land-use patterns and inferences can be made about movement which can help with management decisions and identify source populations.

Microsatellites and transcriptomes Fescmyer

Foraging and migration behaviors have different ecological consequences. Work with *Melitaea cinxia*, a model system because it moves over small area but across patches – colonizes new patches- can be used to identify migratory populations. What are the genes involved in migratory behavior? What is the influence of host on flight pattern? Focus on candidate genes such as troponin T-calcium binding protein in muscle. Transcriptome pyrosequencing using 454 sequencing by synthesis technology. Analysis of gene transcriptome.
Find that peak production of CO2 in weight-supported flight is related to flight behavior. Females and males are very similar. Other researchers showed that distance traveled correlated with CO2 produced.
Troponin T forms 6 different isoforms. Individuals that have certain patterns are better or worse flyers: bigger isoforms, the better muscle contraction and better flight capability. Peak CO2 negatively correlated with small isoforms and positively correlated with large isoforms. Transciptome sequencing of *H. zea* submitted to NRI.
-*H .zea* survive on Bt corn, but are smaller. Particularly in females, those from Bt crops have bigger thorax with respect to abdomen – suggesting that they are conserving flight capability at the cost of reproduction
- metabolic rates of adults lower from Bt corn, not a lot of difference after adjusted for thorax size. Wanted to examine host sources of migrants using isotopes, latitudinal sources of migration using hydrogen isotopes, and variation in gene flow over time and space using microsatellites and markers. Using carbon isotope analysis on catches in PA, getting some C3 insects but mostly C4 insects. This may be away of pulling out migrants; don't expect many C3 insects in PA.
Microsatellites analysis- disparity in data in MS from OP and PA in terms of null alleles. Seeing a lot of homozygote in populations and microsatellites may not be useful, or maybe need to use different markers.

Fall armyworm Meagher

Fall armyworm migrate every season, but no diapause. Has two host strains and there are differences between the two strains but not morphologically. The question was posed whether controlling population in south can control populations in the north? Did C3/C4 strain analysis to see which strain colonizes which host. Corn strain attacking cotton and is coming from local cotton crop. Work done in Brazil looked at genetic makeup and haplotypes bases on cytochrome oxidase I were defined. Brazil and Texas seem to have similar coI haplotype patterns, but Florida and Brazil differ. Haplotype ratios may be used to distinguish populations from different sources. MS and LA have lower 4/2 ratio than

FL. Preliminary data shows AL is similar to the TX pattern, and PA is similar TX pattern, while GA is a mix but is closer to FL. That would indicate that moths from Mexico and Texas are moving NE and FL migration of FAW is limited. The TX and FL mixing is limited. A future research interests are of rice strain and extending studies to the Caribbean.

Transgenics Head and Storer

Bt corn has a number of products expressing different genes – CryIAb and Cry1F are relevant to leps – armyworm and cutworm activity and both on corn borer. Collectively about 50% of acres in corn belt are planted with Bt corn. In southern US there is little adoption. Has to be planted with refuge area, 20% in corn belt and 50% in south. In future have multiple Bt genes together, more products that have armyworm control and better corn borer control, and if adopted more in south can influence pest dynamics. Bt sweet corn effective on corn borers, corn earworm and armyworms but limited adoption.
Bt Cotton – three products commercialized. Effective on CEW and armyworms. Adopted in areas 50-80% of fields. Refuge requirements smaller than for corn. Other Bt based cotton products are in the pipeline.

Not seen shift in tolerance of these organisms feeding on Bt crops, no shift in Bt susceptibility. Pink bollworm has shown susceptibility to Bt cotton, but the host range is very different.

Current *H.zea* Forecasting Update (NIU) Changnon, Sandstrom

Came from a need for forecast (1-5 days out) on a daily basis. Used 40+ years of trap data from northern IL and southern WI to develop forecasts based on correlations of synoptic weather patterns with trap catches. There can be differences on annual basis. Sandstrom discussed the influence of weather pattern on migratory pattern, stay between the high and the low pressure systems. Insects are forced down between cool dry air and warm air Last year's forecasts were sent to researchers and extension leaders only for research and testing. This year's forecasts are available publicly and forecasts expanded to southern Ontario area. Forecasts go from noon of the current day to noon of the next day. Were able to validate the forecast using trap catches; did show that predicted well except for areas to the east of the weather systems where no significant wind events occurred. Want to look at long term and expand to other migratory insects.

http://www.maplecity.com/~sand/cew/imrf.html
future site: http://agweather.niu.edu
also linked to Zeamap webpage from NC IPM grant

Aerobiology modeling tools Isard

This can be used to interface with what was presented by Sandstorm.
IAMS works by dividing the system into 10 km grid and model runs on 1hr time step and model output is displayed daily. Use all the available data sources – such as NOAA, RUC, GFS model, plus NEXRAD radar data for precipitation and USDA crop statistics, plus the monitoring information. Use the classical aerobiology releases model – take off from source, transport in atmosphere and wind dictates direction and speed, back in surface area

dynamics. Described processes in soybean rust aerobiology model. In terms of source area- make certain assumption about source area inoculum load, have an escape function for the number of spores that get out of the canopy; use wind and speed for movement, and adjust for mortality due to solar radiation, and then compute dry (more important closer to the source area) and wet deposition – all parameterized in the model. Also "grow" host in each 10km grid, then based on soybean crop growth stage and other host conditions and factoring deposition, can predict infection as function of temperature and leaf wetness.

There was a comment from the group that pointed out the importance of conveying uncertainty area associated with any weather forecasts.

Delivery and IT tools **Isard and Miller**

Isard discussed the variety of tools available on the public and restricted website. The restricted access site focused on raw data map (observational data), sentinel plot overlay, ability to mine the data, and access to modeling information. Also discussed the tools used by the specialists to communicate information to the public such as populating the public map for each state and ability to provide state specific commentary and management guidelines.

Miller

Pest watch began in 2002, but has data as far back as 1998. This is flash based system that sits on top of the database. The flash allows the creation of an interactive interface with the ability to query data. This site is the first generation of tools. A newer flash based interface built on top of geoserver is being built through the NC IPM funding, and will be available during this 2007 field season. This allows one to consume and push web services. The idea is to make it user friendly. Miller also showed a fusarium head blight system that has a calendar, commentary and 48 hr forecast. In addition to grid based forecasts, can run model at all available stations at any available date and now incorporates other weather networks for the fusarium system. Showed wheat scab restricted site that allows one the ability to view several model inputs at the same time. The idea is to build a historical data. Working on revising the pest watch system to a newer format that will include all previously available tools but will have the web services functionality allowing integration of data across disciples and with other data layers.

Public and Restricted Access Outputs **Fleischer**

Suggest very specific maps of corn earworm we might develop, such as

Diapause Initiation	As day-length shortens and temperature cools	Public
Source Region	(maximum) Pupal survivorship from soil temperature/moisture (abiotic mortality only)	Public
Overwintered Pupal Density	Initialize pupal density from crop infestation? Apply overwintering survivorship	Restricted Access
Spring Emergence	Timing of pupae emerging as adults – diapause termination and post-diapause development	Public

CEW Trap Captures	Visualization of spatio-temporal database. Expert commentary from Extension supported and encouraged.	Public
Crop-specific Oviposition Risk Maps	Combine the monitoring and modeling data with a rule base expressing oviposition preference in landscape for certain crops	Restricted Access
Risk of Adult Deposition	Aerobiological modeling of adult transport: where deposition is likely, and where it is unlikely.	???
	Synoptic weather correlating with transport and deposition	Currently public
Source trajectories	Integrated support for backflow or forward trajectories (HYSPLIT)	Restricted requests, required high temporal resolution
Pyrethroid resistance	Diagnostic-dose or molecular probe assays? Forward trajectories from resistant source populations? Other management based maps	???
Crop-specific oviposition risk map	Landscape-level crop phenology modeled as oviposition preference through a rule-base	Restricted Access
CEW Trap Captures	Visualization of spatio-temporal database. Expert commentary from Extension supported and encouraged.	Public

Whether a map/output is restricted or public depends on the level of confidence of the product.

Shelby drafted three goals to consider:

Our goal is to develop a MAIZE PIPE with dynamic and sustainable information flows that improves management of lepidopterans in sweet corn, and is useful for IPM in vegetables and other types of maize.

more user driven objectives and other crops

Our goal is to develop a Migratory Lepidopteran Modeling and Decision-Support system with dynamic and sustainable information flows that improves management in agroecosytems.

Our goal is to improve our understanding of noctuid migration in North America through cooperative research, such as defining host and geographic sources of migrants.

more research objective

Discussion of objectives:
Some suggested thinking of field corn and seeding corn industries as part of the first objective. Fleisher said the PIPE Concept Note was targeted to minor crops only because of perception of RMA interest in funding minor crops – this may not be correct perception. He also noted that if the system is developed correctly it can be used for other migratory pests. Others pointed out that with biofuels, low contamination thresholds may become an issue. Should the three objectives be combined? Some said yes, and others said they are sequential.

Scott mentioned that extension component is very important to the PIPE steering commit and the funding agency and needs to be emphasized. RMA funding needs to have sweet corn in the wording, but maybe not exclusively so.
Also, may consider applying for area wide funds; those proposal are due end of July but must come from ARS. For ARS, can include all maize, can't work on sweet corn specifically.

Netweaver by Saunders
Used this software to arrive at consensus view about how objects are related hierarchically and helps capture what is known and what is unknown. This, in its full functionality, is a "fuzzy" modeling tool. This is based on organization hierarchy where nodes are Boolean operators, and the values can be read left to right like a rule. Can select a "value" and see what is needed to answer that "value"/question.

Two approaches in thinking of this in terms of mapping relationships using the Netweaver software. One is to start with biology and the other is to start with output products. The group first began with starting with biology. Then the group tried starting from the output products.
The discussion first focused on biology such as producing phenology maps with isolines indicating when field corn is tasling, silking, and senescing. Scott said those crop phenology models are available. Although the group first thought to focus on three crops for phenology maps, the list was much expanded to: field corn, soybeans, cotton, sorghum, peanut, sweet corn, seed corn, tomatoes, snap beans, tobacco, and some non-crop hosts
Scott discussed how phenology maps are developed- using historical USDA NASS data and using greening and correlate statistics with greening on a yearly basis and then based on those coefficients figure out phenology during the current year. Need temperature, get county level data, enough – about 10 years of record, and daily temperature and precipitation.

We conducted an exercise of drafting an understanding of objects that would influence a lepidopteran aerobiology modeling system, using full-group discussion.

1. A working document within NETWEAVER was created : called LAMS-PIPE-IT.
2. Objects (typically map layers) were defined that influence LAMS-PIPE-IT

3. These objects were organized into a dependency network. Most of this building of relationships among objects was started from the point-of-view of the mapped outputs. Thus, a key object (a goal) was called "Outputs of the PIPE".
4. In a few cases, we annotated the objects with a few comments.
5. We did not reach the level of defining data sources for each object.

Outputs of the PIPE were defined as:

Host Phenology Maps
Lep Phenology Maps
On-Crop Oviposition Risk Map
Source Region Map
Overwintering Survival Map
Time of Spring Emergence Map
Lep. Trap Catch Map
Diapause Initiation Map
Diapause Termination Map
Adult Deposition Risk Map
Resistance Maps

And the topics that influence Outputs of the PIPE were defined / discussed as:

Adult Deposition Risk Map
AGE
Air Temperature
Black Cutworm
CEW
Cloud Cover
Cotton
Daily Air Temperature
Detoxification Mechanism
Diapause Termination Map
Diapause Initiation Map
Diapausing Ieps
Different Toxins
Dose
ECB
Facultative Age Related Behaviors
FAW
Female nutritional Status
Female Status
Field Corn
Frequency of Resistance in source populations
Frequency of Resistance at Trap Location
Historic Temperature Records
Host Distribution Map
Host Phenology Maps
ID Guides
Land Cover
Lep Phenology Maps
Lep. Trap Catch Map
Local Dispersion
Local Host Plants
Local Host Type
Local Insecticide Usage
Local presence/absence of host plants
Long Distance Dispersion
Lunar Phase
Mated Status
Multiple interpolation methods
NASS
Nectar Sources?
Non-Crop Hosts
Non Diapausing Leps
Obligate Age Related Behaviors
On-Crop Oviposition Risk Map
Other Crops
Overwintering Survival Map
Oviposition preference rule base
Peanuts
Photoperiod
Precipitation
QA/QC
Resistance Mechanisms
Resistance Maps
Season specific behaviors
Seed Corn
Sex
Single vs. Multiple genes
Snap Beans
Snow Cover
Soil Moisture
Soil or Air Temperature
Sorghum
Source Region Map
Soybeans
Spray History
Spray intervals
Spray patterns
Sweet Corn
Synoptic Weather Conditions
Tillage method
Time of Spring Emergence Map
Tobacco
Tomatoes
Trap Catch Records
Trap Location
Trapping intervals
Trap Service providers
Trap Type
Tri-fold brochures
True Armyworm
VelvetBean Caterpillar
Western Bean Cutworm
Wind Directions
Wind Speed
WWW based trapping support

A dependency network - the set of relationships among these objects –- was built into an html file. This dependency network will be placed on the website that contains these minutes.

To view this, click on any of the html files that display a browser icon. You will be at a page for an object.

To best see the relationships as developed in this meeting, scroll to the object called "Outputs of the PIPE".

Move among any objects .

Return to "Outputs of the PIPE" object to re-orient.

Here are some other items people brought up:
-Couple insect and host phenology and find out how that influences movement.
- Determine the areas in the south where host is corn, relative to cotton, or sorghum in other areas.
- Scott noted that aerobiology models are typically most sensitive to what we tried to address in our "Source Region Map".
- Biofix that can determine movement and then make an estimate how many move.
-Scott enquired if corn has senesced and conditions exists how many will move; then how many move if other hosts are present in the area such as cotton or sorghum.
Something else to consider -Takes it a while after pupal eclosion before flight muscles develop- another rule base. How does gender and mating-status figure into noctuid migration? In spring move fast as weather is fast, no reason to shut down reproductive system . In the fall, go into reproductive diapause because of slower movement system- males don't respond to pheromones in the fall and eggs don't mature as quickly.
-Group agreed to consider males and females together as a "unit". However, males in several species often emerge earlier than females, but the group felt that it may not make a significant difference.

Isard discussed ecological scaling. He noted that you need to consider spatial and temporal scaling. He showed the space and time dimensions of monarch butterfly life history as a prototype for ecological scaling. Monarch group got together and like this group identified system drivers.
Backflow is important to consider in term of pyrethoid resistance.

Requirements for each map were discussed, and some notes put into the object itself. Some additional notes about these objects include:
Phenology maps- precipitation, temperature, soil moisture, local host presence/absence from NASS or land-cover. (During the second day the discussion focused on using more of host distribution map to quantify the type of crop in each cell)
Lep phenology –divide them by biology: diapausers (corn earworm, western bean cutworm, European corn borer, black cutworm, true armyworm) versus non-diapausers (fall armyworm, velvet bean caterpillar). Drivers include temperature, photoperiod and host quality (include Bt or not Bt crop??). Obligate age related behavior (only for adults). Facultative related behaviors
On-crop Oviposition Risk Map- develop oviposition preference rule base coupled with phenology and status of the female such as age(does mated status need to be considered): rule base from Stinner paper and existing data??. Simple rule base if moths are present and have receptive crop. (Overlay this with the NIU idea of having traps as individual dots)
Consider the interpolation to use to estimate across the grid.
Source Region Map –spring emergence map, insect phenology maps, and trap catch map.
(side note: ground truthing/validation - what time basis)
Overwintering Survival- Just proportion of survival based on a rule base : such as no survival above I-80; how to decide on gradation of survival below I-80 – use function of soil temperature at ~5cm, or 3-

10cm depth maybe using CLIMAX model to develop the rule base, tillage (may acquire from NASS statistics), soil moisture, and host distribution map (land cover map)
Spring Emergence – Just the timing of spring emergence
Trap Catch Map – GPS, service provider, trapping interval, local host plants, trap type, pheromone type, observation date, (optional) crop phenology stage, moths caught, gender (optional), and insecticide use
(Develop id guides to help with identification)
Diapause Initiation Map – photoperiod and air temperature and lep phenology map
Diapause Termination Map – soil moisture, soil or air temperature, photoperiod.
Adult Deposition Risk Map – precipitation, local and long distance dispersion

Local Dispersion – lep and host phenology, precipitation, host distribution, air temperature, maximum wind speed, lunar phase, trap catches as indication of density, source region map

Long Distance Dispersion - – lepidoptera and host phenology, host distribution, precipitation, air temperature, maximum wind speed, lunar phase, trap catches as indication of density, synoptic weather conditions and wind direction, source region map

Resistance Maps – specific maps for different toxins: frequency of resistance at source areas (needs to be provided from tests)/related to trap locations, Local Insecticide Use, long distance dispersion, local dispersion, resistance at "final" locations, resistance mechanism (different toxins, single or multiple alleles, dose- which includes spray patterns, detoxification)

June 29th

As a Review of the maps developed yesterday:

- Host Maps- phenology of major host crops and the information needed to develop them. It was decided that this will be an internal map during this morning's discussion. A question arose over "pre-canned" phenology models or driven based on planting date provided by users and model phenology based on those user inputs. Run "pre-canned" phenology models on a large scale, in addition to allow users to provide their own parameters and run those on a more localized scale. There might be difference in the source areas vs deposition areas, number of plantings, etc. Scott said the user level input would be available to restricted user level, where restricted is defined as a trained user.

Scott asked participants to consider who will be using these maps and then how to deliver them.

- Lep Phenology Map - recapped the parameters that would go into developing this map. The group decided that this would be a public map and the ability to overlay it with trap catch data as a method of validation. This product can be used by processors and growers to support better management decisions.

If this is set as a service, through DRM can control who and what applications have access to specific products.

Scott mentioned that in a PIPE proposal there should be a table listing each map, type of use for the map, and why the map was important. It was also suggested that validation, how these maps can be validated, should be included in this table.

- **On-crop Oviposition Risk Map** – Preference rule base is the weak point, but the best that is available, and data for all the crops is not present. This preference varies by species. This should be a public map with audience being the grower and

processors that can be used for individual pest management. Could support those conducting monitoring, i.e observers. This could be of use to the forecasting team.

- **Source Region –** This will be an internal map. This is where the population genetics, carbon isotope, specific signatures, and pyrethroid resistance research work can be added. Although RMA will not support pure research, research can be brought in to support the effort and fill in knowledge gaps.
- **Over-wintering Survival Map –** Trap catches for non-diapausingrs species can be important. Internal for now but may become public with time. May be validated based on catches that occur early in the season, but the issue arises of defining locals and migrants. For non-diapause, need to know non-crop hosts. In general, for diapausers consider non-crop hosts and trap catches in generating this model map.

* Scott mentioned placing maps in logical order and identifying knowledge gaps.

- **Time of spring Emergence** – Lep phenology and diapause termination. This was decided to be an internal map. Should be available to observers. This will be a static map for the year, unless adjusted based on bio-fixes. This is for diapausers only.
- **Trap Catch Data –** This will be a publicly available map. PIPE is likely to support effort to standardized trapping protocols. There might be a need to standardize/research pheromones. It's critical to note that this is the only map that measures the actual organism occurrence in the field, but only measures the males and at one point in the life stage. There is a lure that attracts both males and females but is not currently used in regular field trapping.(Good data for zea that trap catches correlate with larval density.) For some species, these catch numbers can be used to establish thresholds.
- **Diapause Initiation –** Applicable to non-adult overwintering diapausers only and it should be a public map. Used as a signal to stop sampling (can be used to see a reverse migration – as sampling will occur through a later time period) for observers and when to stop spraying for growers. This can also be of use to researchers and inform source region map. Potential to help understand migration patterns.
- **Diapause Termination Map** – The cold impacts emergence and not part of termination. This is an internal map applicable for diapausers only.
- **Adult Dispersion Risk Map –** made up of local and long distance dispersion. This is a public map that could be of use by growers, CCAs, seed producers for field corn, and extension. Can be verified by catches, and use catches as the bio-fix.

* should consider season specific behavior, could impact reverse migration. Could impact the source region later in the season when reverse migration occurs. The role of reverse migration is not well know in relation to pyrethroid resistance,

Make a note in the host distribution map of those hosts that provide nectar.

- **Resistance Maps –** This is a public map, with consultants, industry – otherwise known as protection (chemical companies), growers, seed company, processors, extension, and researchers as the base. Live trapping and dedicated sentinel sites required. If others are willing, will be based on AVT results. Ideally will need a lab to conduct dose/mortality studies with extended capacity.

Action Plans:

There was a discussion about creating a communication structure for others interested in migratory Lepidoptera, maybe using the structure of ESA, which can be used to create a working group with web-space. However, some pointed out that non-ESA members would not have access to that communication structure. Another idea is to set up a subgroup of the regional aerobiology project. It might be possible to tack on a day at the NCERA-148 meeting in the fall in MN, on October 12th; - but we also asked that the date be moved up to Oct. 3rd if possible - a number of the same people will be there. Another option is to add on a half day at an entomological meeting.
What project proposals can be developed?

- Scott thinks PIPE might be the best opportunity; call for proposals will come out sometime in September and the turn round to submit proposals will be very short. For a PIPE proposal, how the information is to collected and communicated in a timely manner is going to impact IPM and how appropriate people will be engaged. This would involve letters of support from collaborators. Scott suggested that another consideration is that the proposal comes from another entity besides PSU, due to the amount of PIPE work being done by PSU (amount of funds flowing through PSU). Scott mentioned that the best approach is to be ready to respond to RFP.
- Another option is to go through RAMP; tried before but did not get it. However, have not received feedback from the first proposal, might want to wait for that before considering that option. It will come up again in the winter. RAMP allows the focus on research that PIPE doesn't really allow. Fleisher will circulate the revised RAMP proposal to the group after he receives feedback from the first submission, sometime later in the summer.
- Another optional is the organismal NRI grant; that is the closest deadline. The concern here might be the validation component.
- Another funding option is ARS Area-wide. Questions arose about regions, but that does not seem to be restricted. Geared on idea of bringing together tools that exist on suppressing population on area-wide scale. That program might have funds as not many proposals have been funded. Could Bt-corn technology be considered – that might be applicable as an area wide suppression tool, if the angle is different from what's been explored already – such as modeling transgenic or multiple toxin effects. Maybe someone should contact that program and see if they would entertain a proposal; if so, materials could be put together quickly. Suggest that in several kinds of maize deployment of trans genes is influencing things in a area wide basis. Develop models and validated statistical tools. An example program can be corn-borer. This could be a year program. Use existing data and statistical modeling and long time series analysis to determine the extent of suppression. How suppression in some areas has impact in other areas- using models – and some model s already exist that can be used. How trans genes for noctuids can influence management on large spatial scale using LAMS system. Some aspects for a proposal already exists, and so does preliminary data as written up as part of the RAMP proposal ; just some additional wording pertaining to the items discussed today. Will wait to hear from Tom in regards to the area wide. Has to clear the Midwest area office. Having others such as Ryan from southern ARS would be advantageous- the more the better as long as the budget is practical.

The group returned to the question of whether they want to become a working group within the NCERA 148 aerobiology group. There is a website already for that group, and a new one will be available soon. Giving this group an official umbrella to work under, may give more validation for the PIPE steering cm. Can schedule a half day working group session before the NCERA meeting. The timing may be optimal because most of proposals will not be due before then (except for NRI). Under this, could develop communications tools such as host and list serve. Isard said that the NCERA can host that and a website can be used to post documents and suggestions. Links can be made to existing NIU forecasting site. The group agreed to developing a LAMS working group under NCERA148 (committee on movement and dispersal of agricultural important biota) and to develop a listserv and a website. The NCERA meeting is now tentative scheduled for 11-12th of October; the LAMS group meeting can be scheduled for the 13th. However, this is the time of a pest management meeting for cotton entomologists, so there might be a conflict. An idea was circulated to move the 148 meeting to a week before that. This has to be approved by the NCERA group before the date can be approved.

The group discussed, especially in regards to a potential PIPE proposal, the importance of a communication plan that addresses communication with stakeholders and among the "specialists" and "observers". Another aspect of that is the role of a national coordinator. Something else to address are mechanisms to develop and review protocols; the current IPM PIPE uses annual workshops. Sustainability of the system is another concern that should be considered. In order to evaluate the effectiveness of the system, for the end users (growers), it would be helpful to design LAMS to include an economist (maybe Paul Mitchell?). There was some discussion of contacting ERS to do an evaluation, as they did for SBR, but that may not be the optimal option as they have their on priorities. The group felt the best option is to incorporate the group's own economist. Basing an economic evaluation on processing industry could be a good way to handle economic analysis. Hutchison agreed to lead the effort from the Midwest, and he felt the NCIPM center should be supportive.

Respectively submitted,
J. Goloard
S. Fleischer

Appendix I – Attendees at LAMS Meeting – June 27-29
Penn State, University Park, PA

Name	Address	Phone	Email
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Unable to attend due to cancelled flights:

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Roger Leonard	rleonard@agcenter.lsu.edu

Appendix II: Planned agenda:

Design of a Lepidopteran Aerobiology Modeling System

Day 1 (6/27) – Travel & Social: sufficient food to serve as dinner

Day 2 (6/28) – 117 Earth Engineering Sciences Building

8:30 – Noon : Strategic Planning, Science Status, and Defining our objective

8:30 – Welcome	Fleischer
History of PIPE	Isard
Current status or relevant grants	Fleischer
Legume PIPE Structure and Future PIPES	Ayers

9:00 – Science status updates (10min each – interrupted by 10:30 coffee break)

Monitoring at semi-continental scale	Fleischer
Pyrethroid resistance	Hutchison
Defining host sources (C-isotope, gossypol, soybean)	Head
Microsatellites and transcriptomes	Fescmyer
Fall armyworm	Meagher
Transgenics	Head and Storer
Current *H.zea* Forecasting Update (NIU)	Changnon, Sandstrom
Aerobiology modeling tools	Isard
Delivery and IT tools	Isard and Miller
Public and Restricted Access Outputs	Fleischer

10:30 BREAK (coffee, water, tea, bagels, fruit)

11:15 Define our objectives — Fleischer

NOON to 1 pm : Catered Lunch

1:00 – 5:00 : Drafting LAMS — Isard and Saunders

Quick intro to Netweaver	Saunders
Ecological Scaling	Isard
Conceptual Model	
Space and Time Dimensions	
Life stages: timing, density, transfer equations	Fleischer, Hutchison
Discussion	
Model Output and Deliverables	

5:00 : Adjourn

Day 3 (6/29) – Earth Engineering Sciences Building

8:30 – Review	Isard, Saunders, Hutchison
9:00 – Discussion	Hutchison, Fleischer
10-noon – ACTION PLANS	Hutchison
Noon – Adjourn	