Modeling BMSB Phenology

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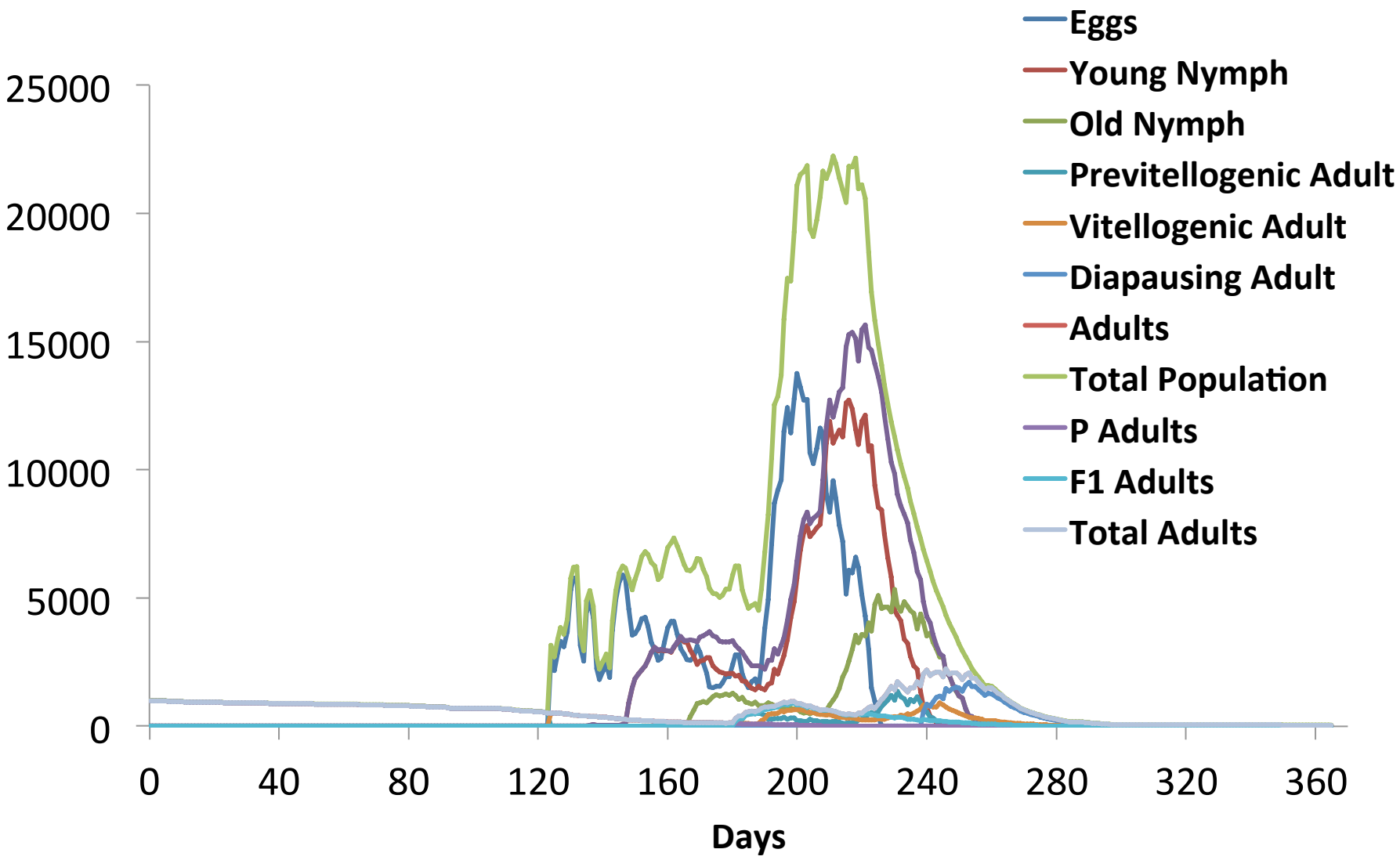
Nielsen, A. L., S. Chen, and S. J. Fleischer. 2016. Coupling developmental physiology, photoperiod, and temperature to model phenology and dynamics of an invasive Heteropteran, *Halyomorpha halys.* Frontiers in Physiology 7:165.



How many generations

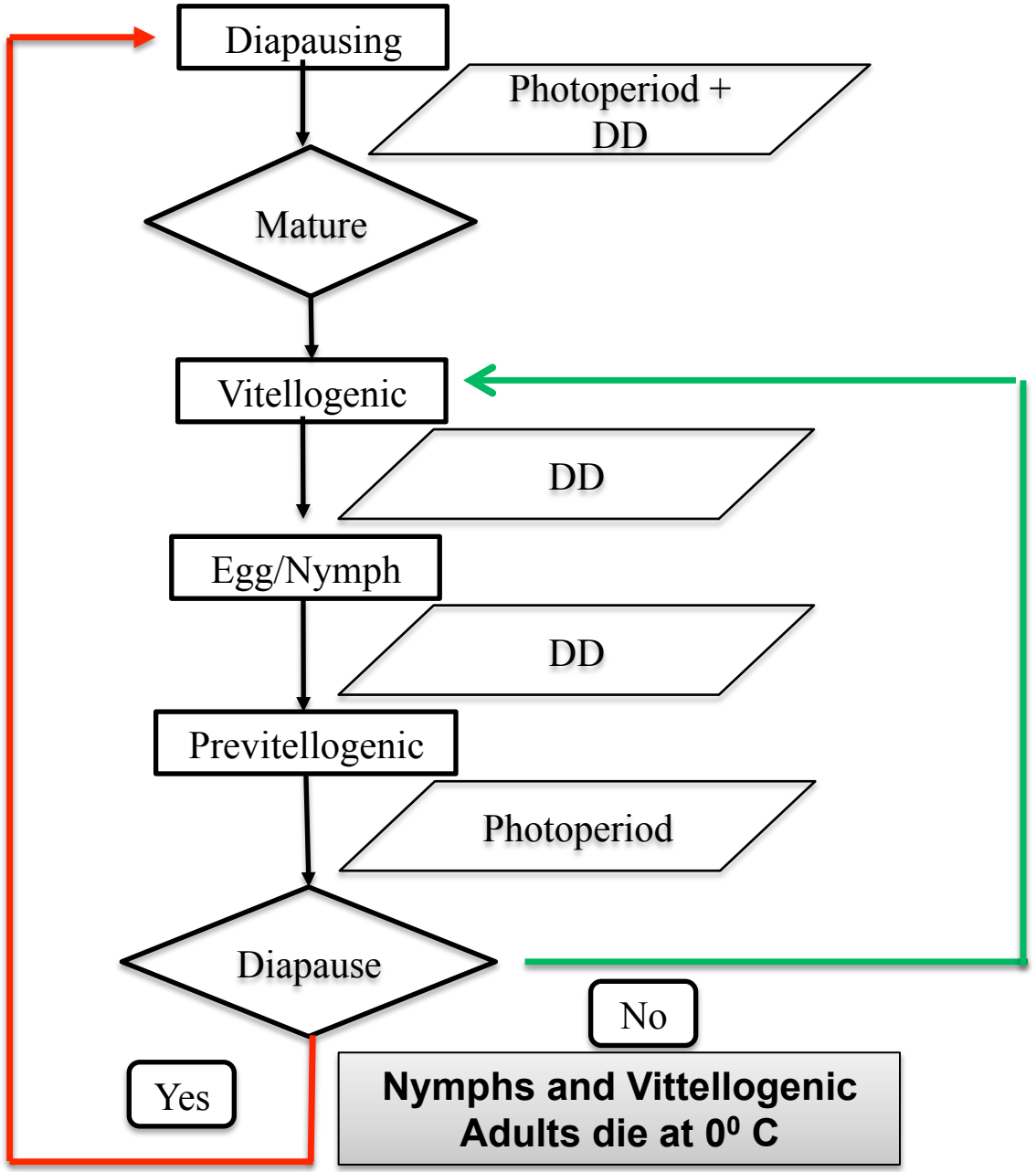
- ✓ Logistics of sampling and management
- ✓ Variation in behavior among life stages
- ✓ Risk of invasion and establishment

Challenges

- ✓Diapause as adults, present as adults in spring
- ✓Poor biofix
- ✓Patchy distribution and high mobility
- ✓*Extreme* overlap among life stages

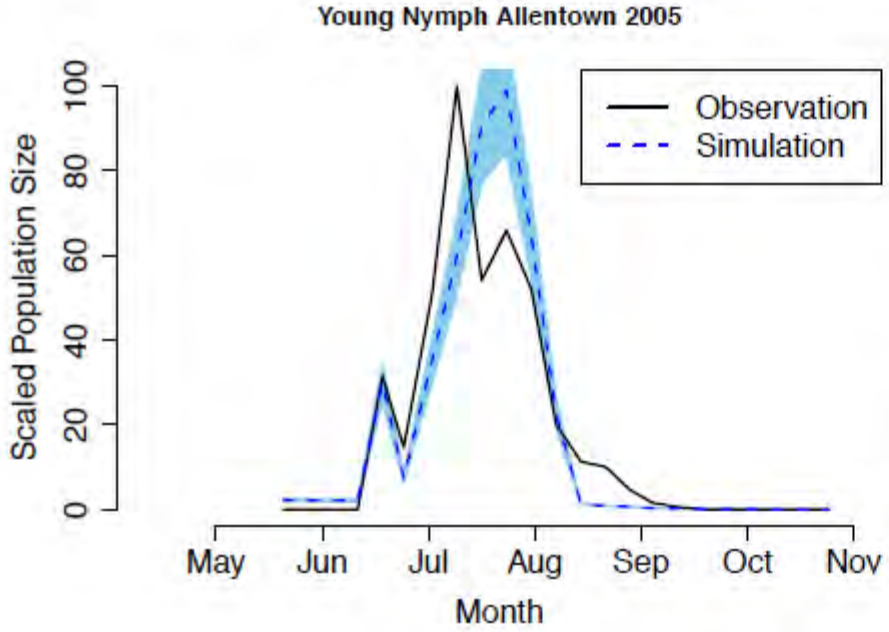
Individual-based (agent-based) modeling approach

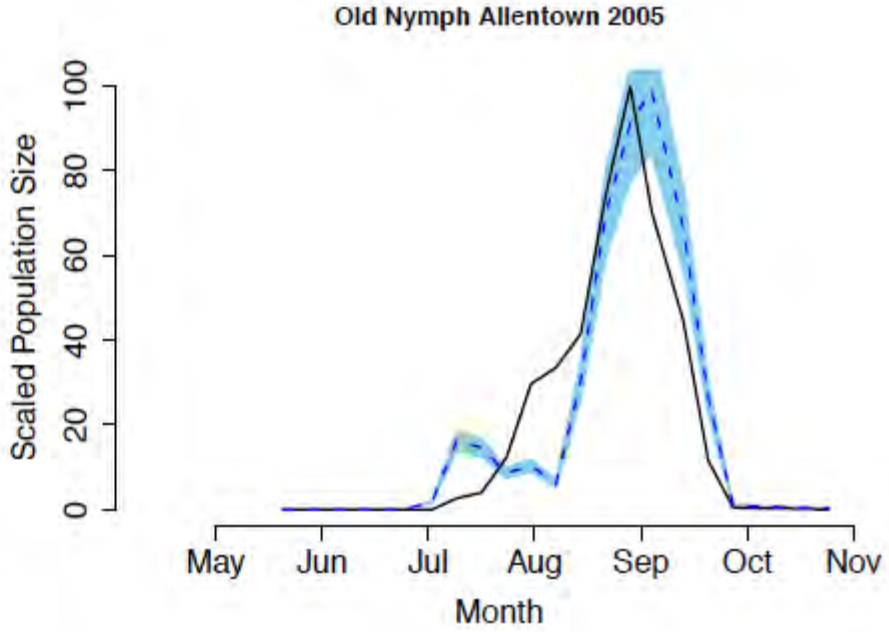
1000 individuals. Results pooled from 100 runs per simulation

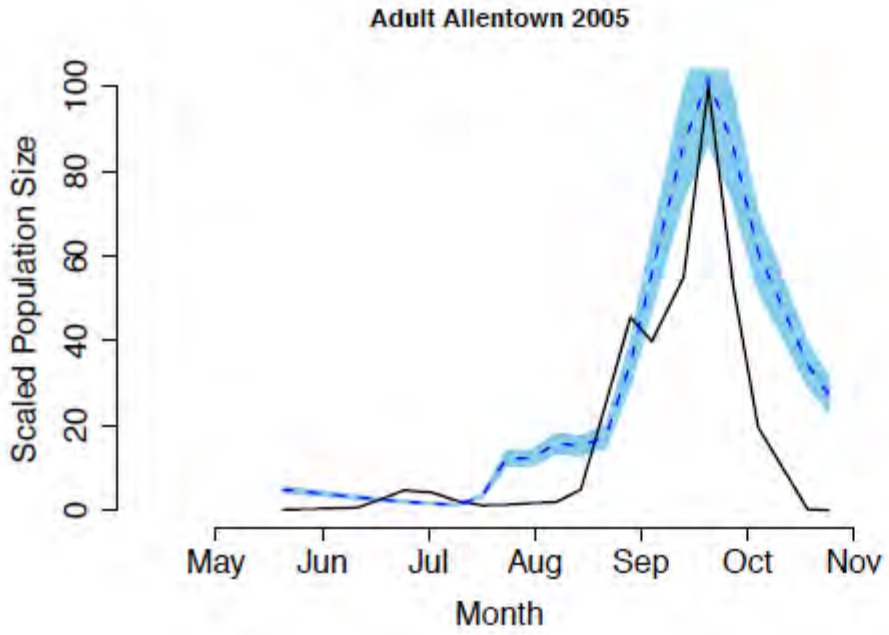


Abiotic Drivers Stochastic Processes

Life Stage	Process	Stochastic	Drivers
Adult	Overwintering survivorship	X	Time
	Diapause termination and induction		Photoperiod
	Preoviposition		Temperature
	Fecundity (clutch size, interval, number)		Time
	Sex Ratio		
Eggs and Nymphs	Survivorship	X	Temperature and Time
	Development Rate and Thresholds	X	Temperature and Time



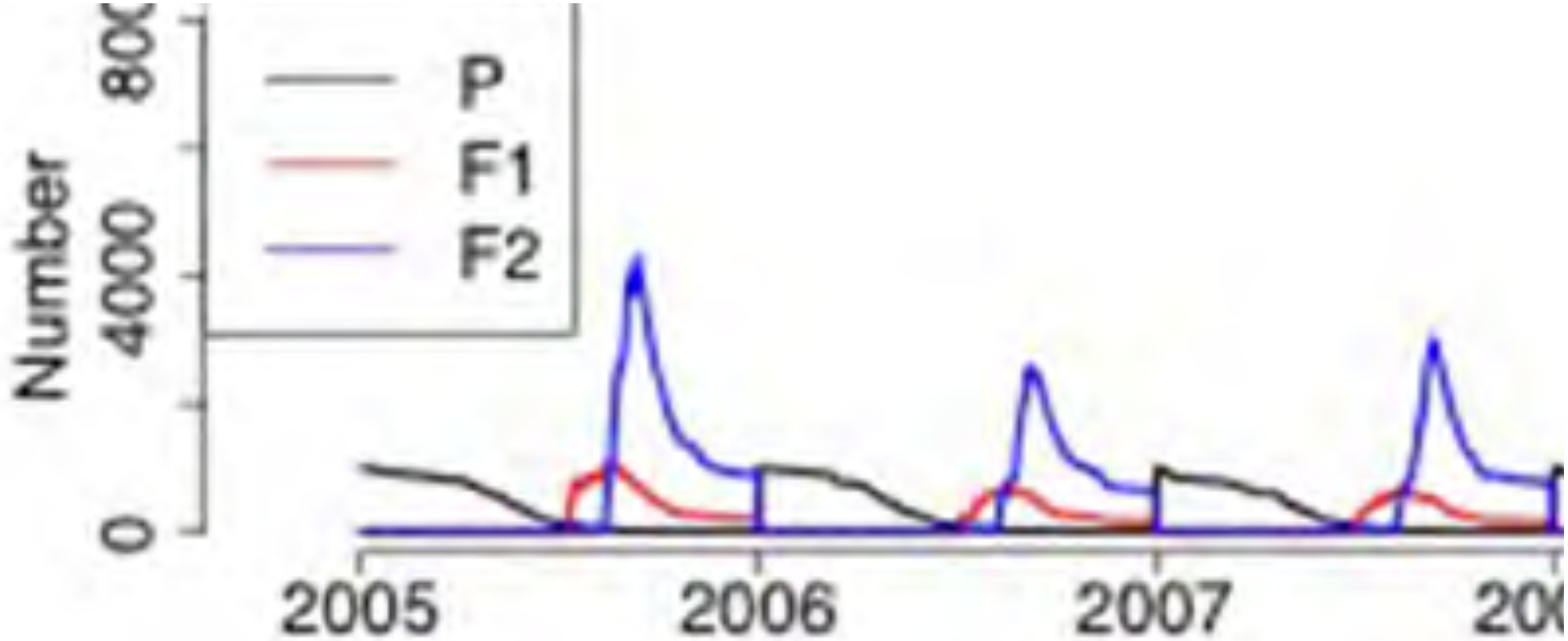




Validation Trials

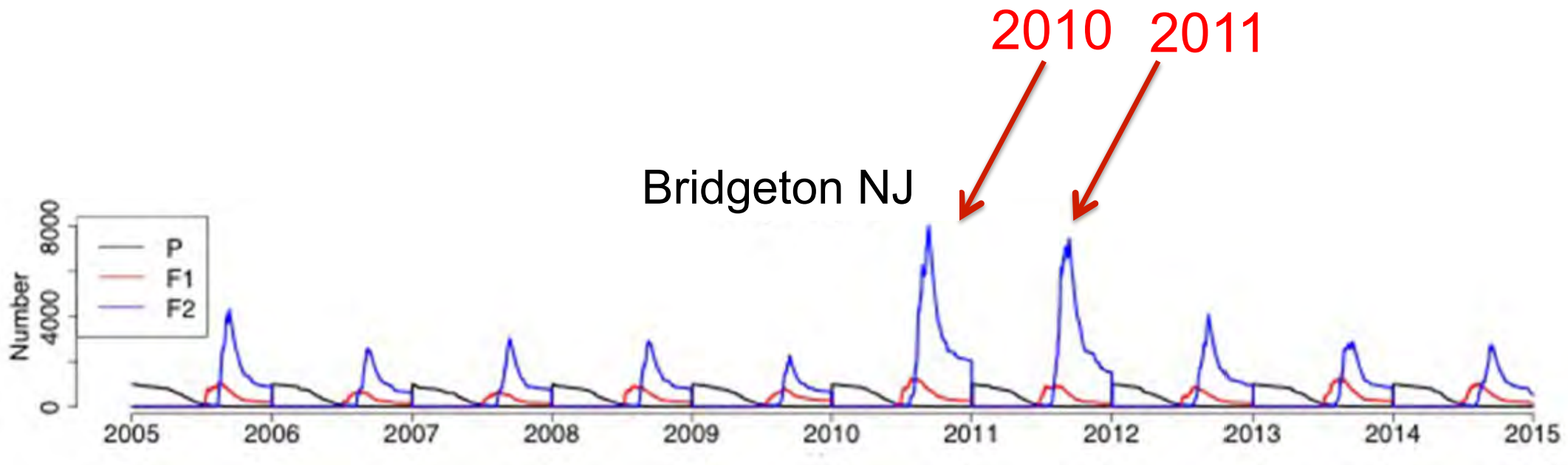
Allentown, PA

2005


Number
0
4000
80
P
F1
F2
2005
2006
2007
20

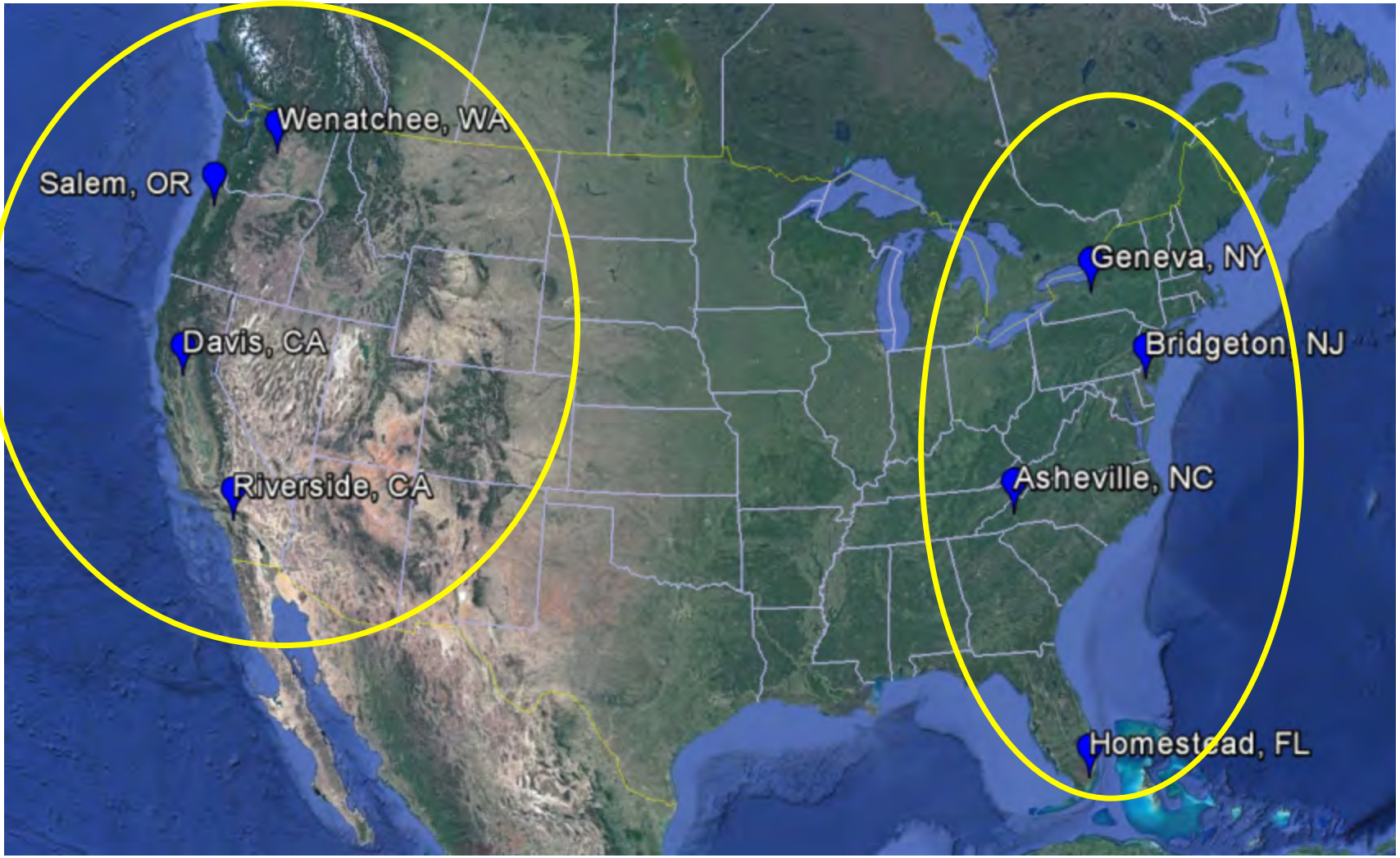
Population Dynamics at Bridgeton, NJ, 2005 - 2015

Years with high damage (2010, 2011) had higher simulated populations



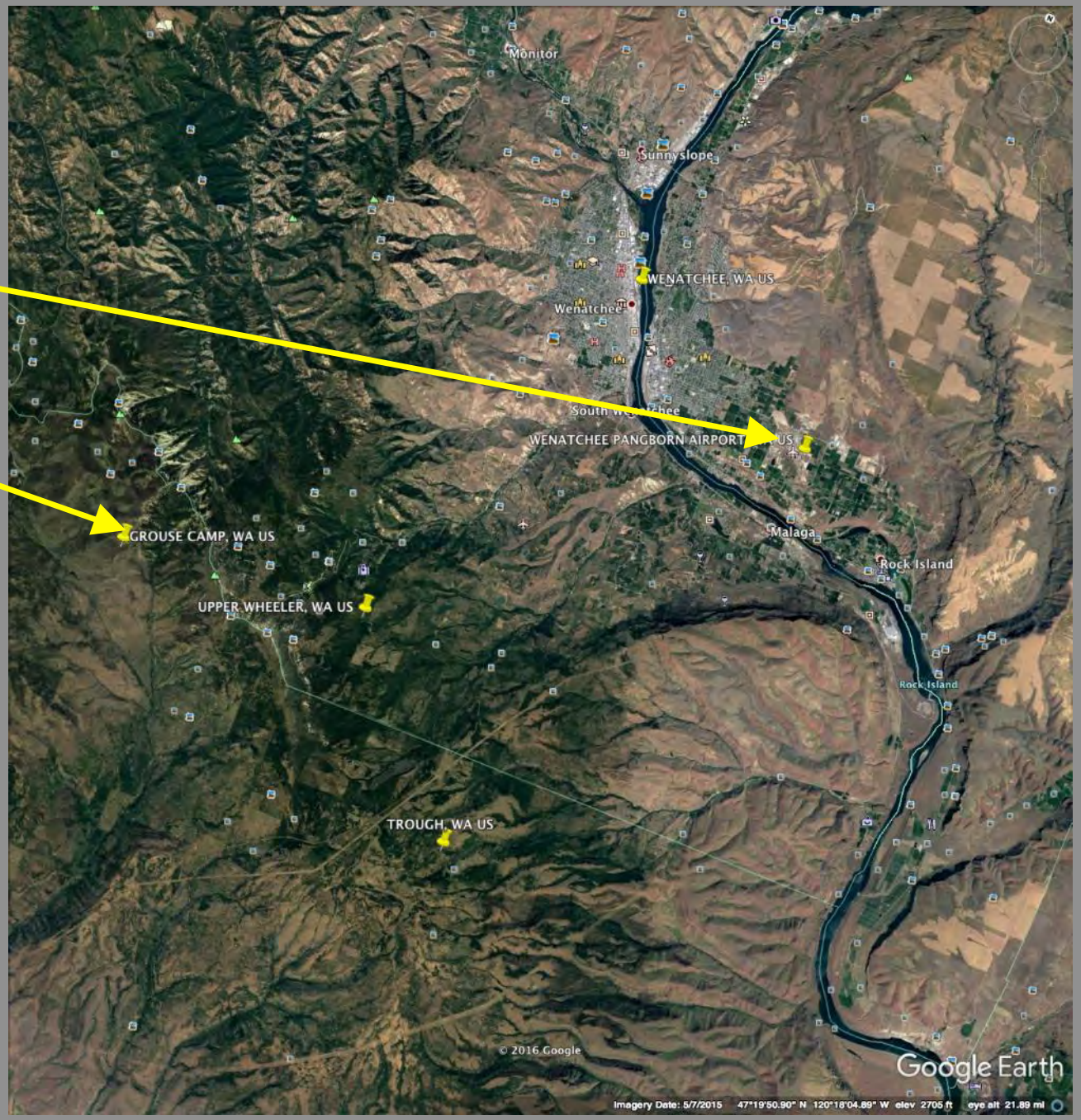
Applied model to:

- ✓ Eight locations: latitudinal gradient
- ✓ Current climate : 2005 - 2015



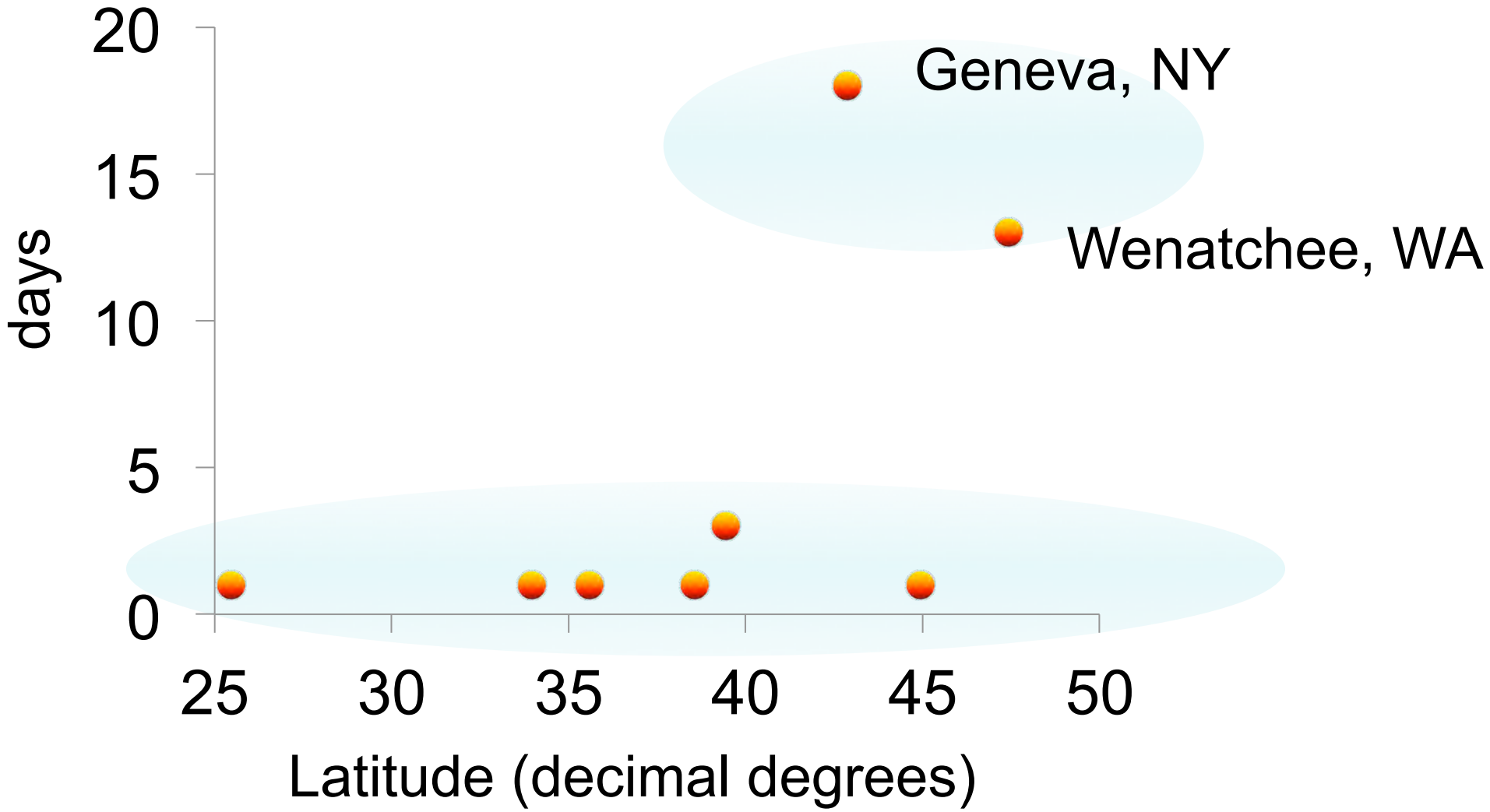
Wenatchee Airport

Grouse Camp



Nielsen, A. L., S. Chen, and S. J. Fleischer. Corrigendum published in 2017: Frontiers in Physiology 8:568. doi: 10.3389/fphys. 2017.00568

Range (days) for overwintered adults to initiate oviposition, 2005-2015

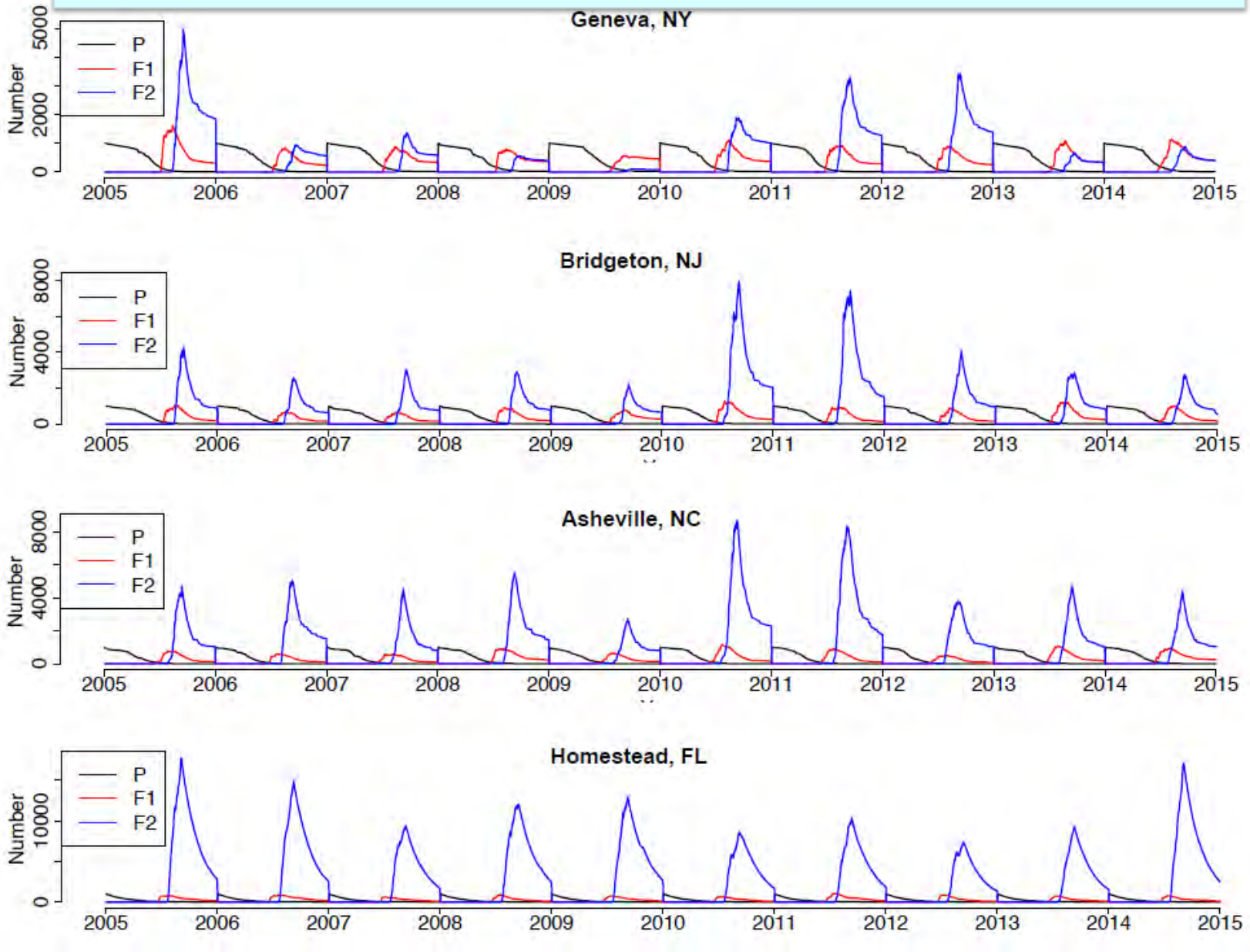


Days from beginning to end of adult eclosion, 2005-2015

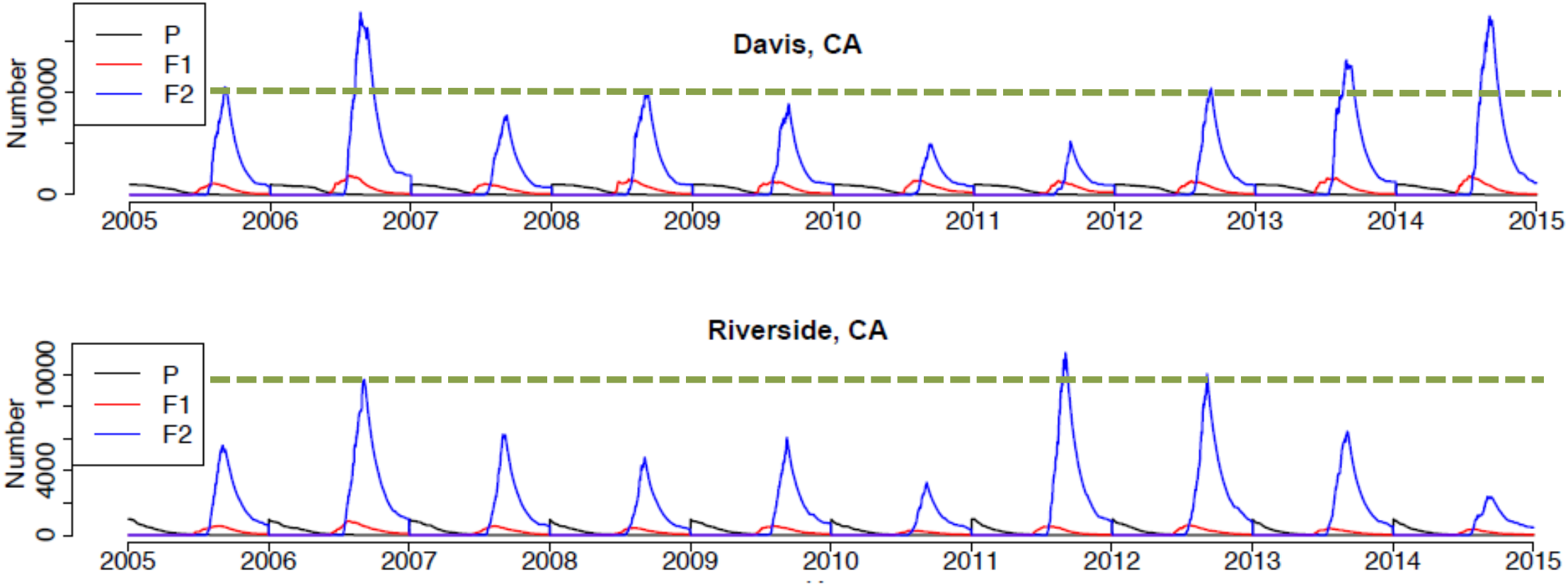
F_1 adults

F_2 adults

Adult Population Size by Generation
note scale: 5,000 in Geneva, 15,000 in Homestead



Adult Population Size by Generation
note scale: green line @ 10,000



Two week difference in non-diapausing range
Upper temperature threshold

How Many Generations?

Who overwinters?

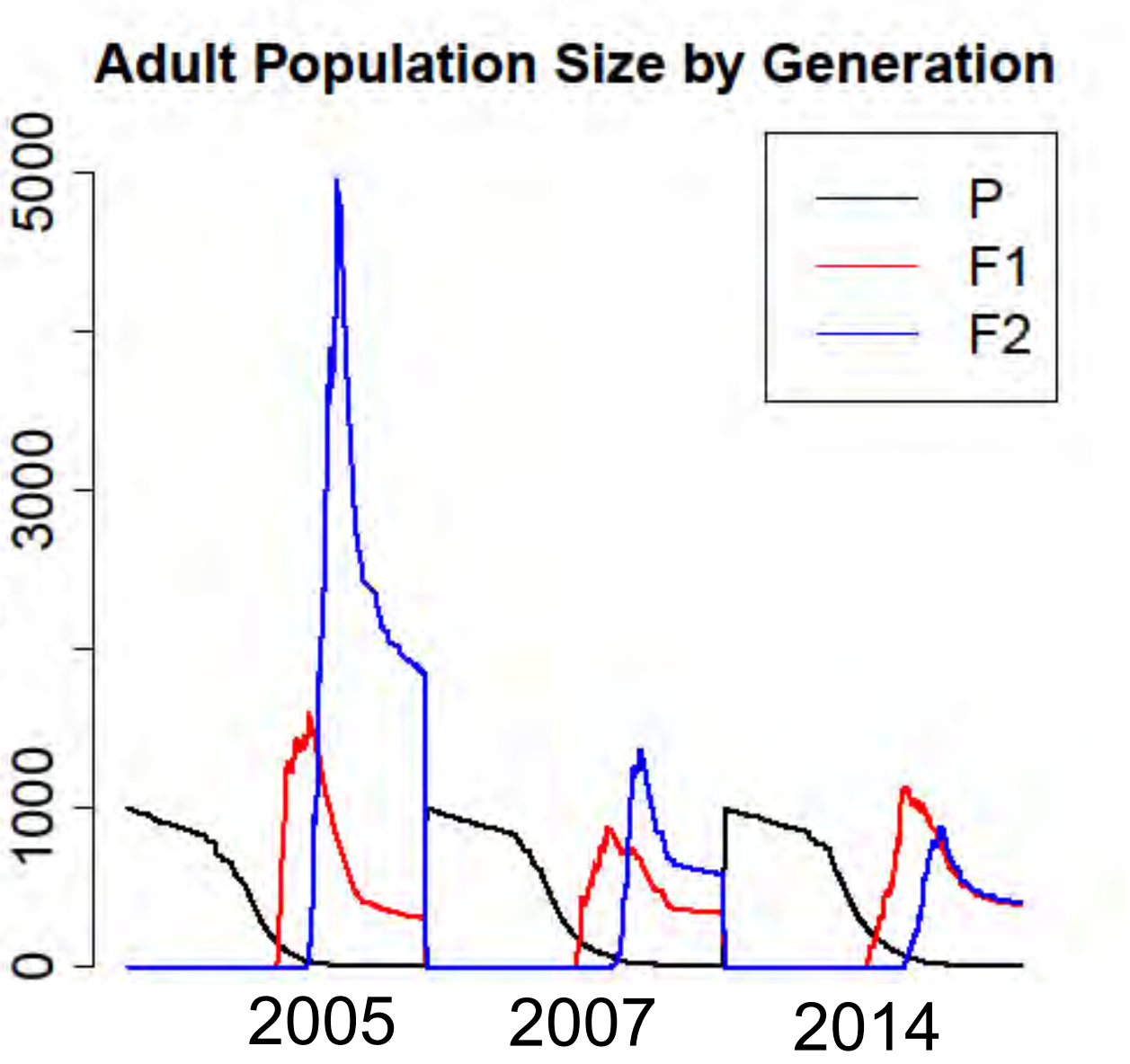
‘Physiological’ Life Stage May Affect:

Behavior

Management

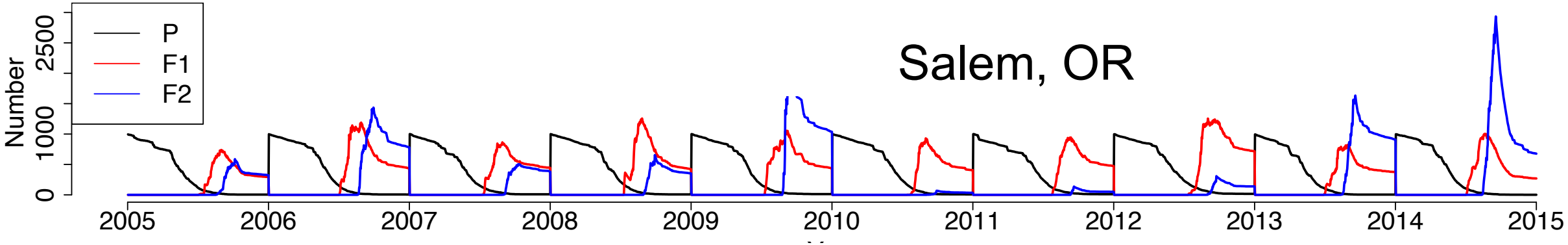
Who overwinters?

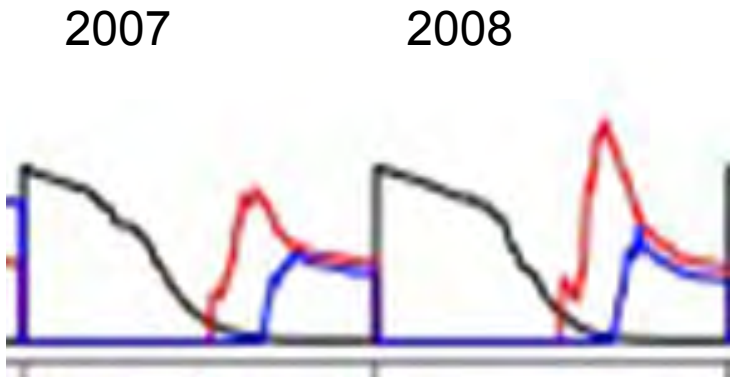
Geneva, NY

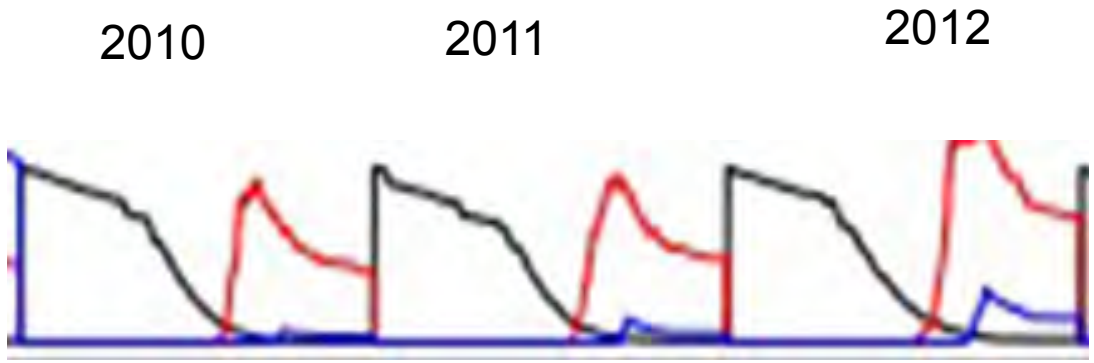


Adult Population Size by Generation

Salem, OR







Build a Graphical User Interface

- Use it in the Areawide BMSB Project
- Design it to be adaptable for other insects
- Develop Tools and Resources For Areawide IPM

Brown Marmorated Stink Bug (Galaxy Version 1.0.0) Options

Select a location

Asheville

Latitude of selected location

35.6

Select dataset containing temperatures

119: asheville2014.csv

Enter the year for the temperature data

2004

Number of replications

3

Critical photoperiod for diapause induction/termination

13.5

Adjustment rate for egg mortality

1

Adjustment rate for nymph mortality

1

Adjustment rate for adult mortality

1

Adjustment oviposition rate

1

Adjustment of minimum clutch size

0

Adjustment of maximum clutch size

0

Adjustment of DD accumulation (egg->young nymph)

0

Adjustment of DD accumulation (young nymph->old nymph)

0

Adjustment of DD accumulation (old nymph->adult)

0

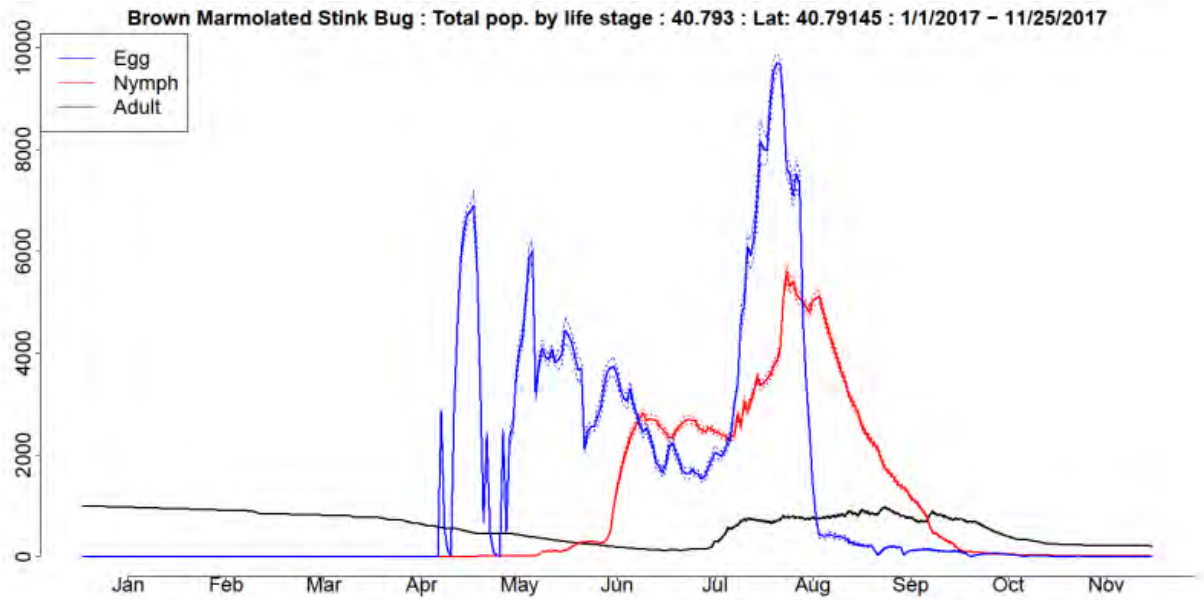
Plot SE?

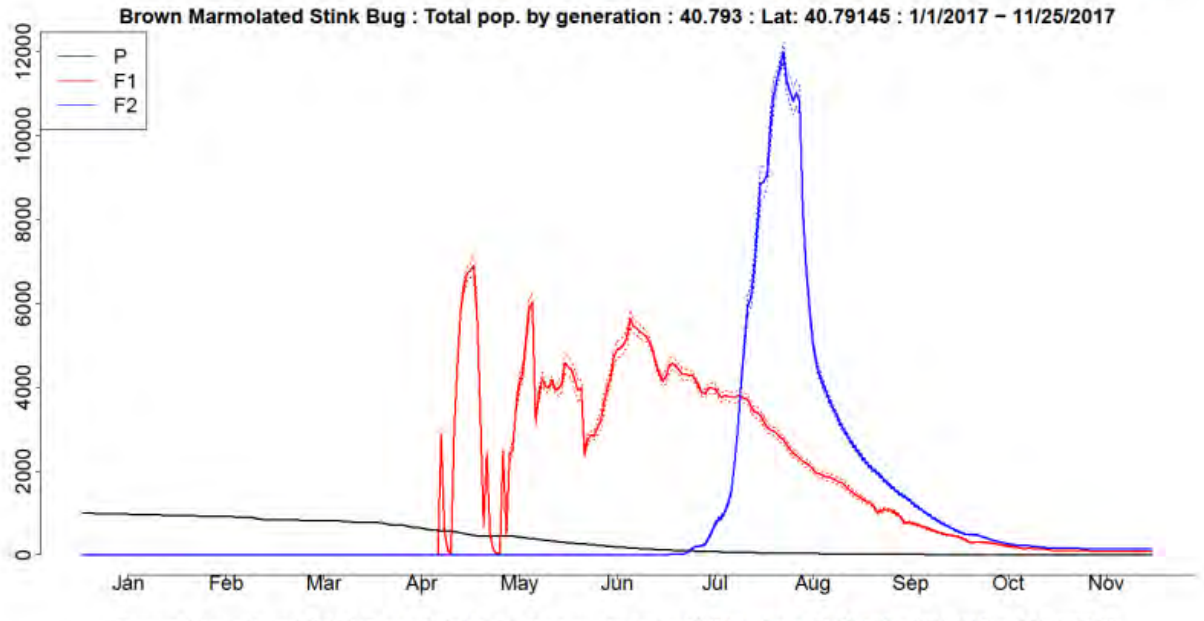
No

Execute

What it does

BMSB prototype tool.





Develop Tools and Resources

Min / Max Temperature – from January 1 to today:

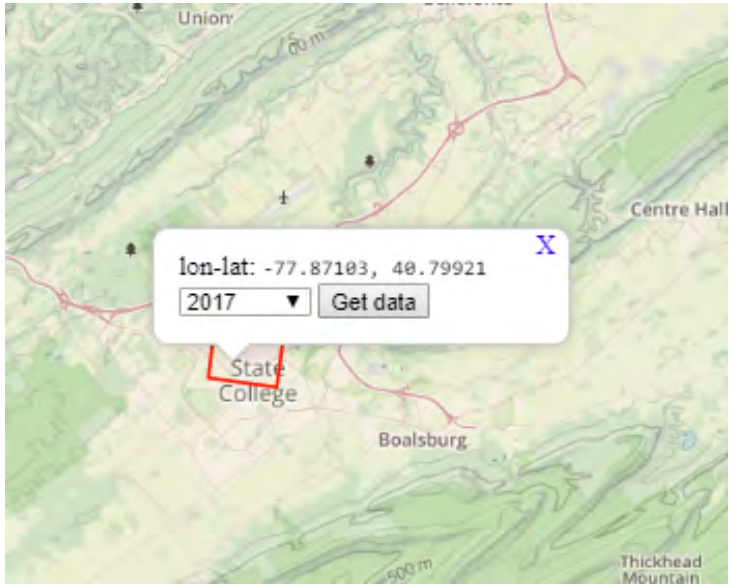
National Center for Environmental Prediction (NCEP) www.ncep.noaa.gov
Un-restricted Mesoscale Analysis (URMA)

Develop Tools and Resources

User / Webservice Access to URMA

www.pestwatch.psu.edu/minmax/index.html

Zoom > Select > “Get Data” > csv file



Develop Tools and Resources

NOAA NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Formerly the National Climatic Data Center (NCDC)... more about NCEI »

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Quick Links

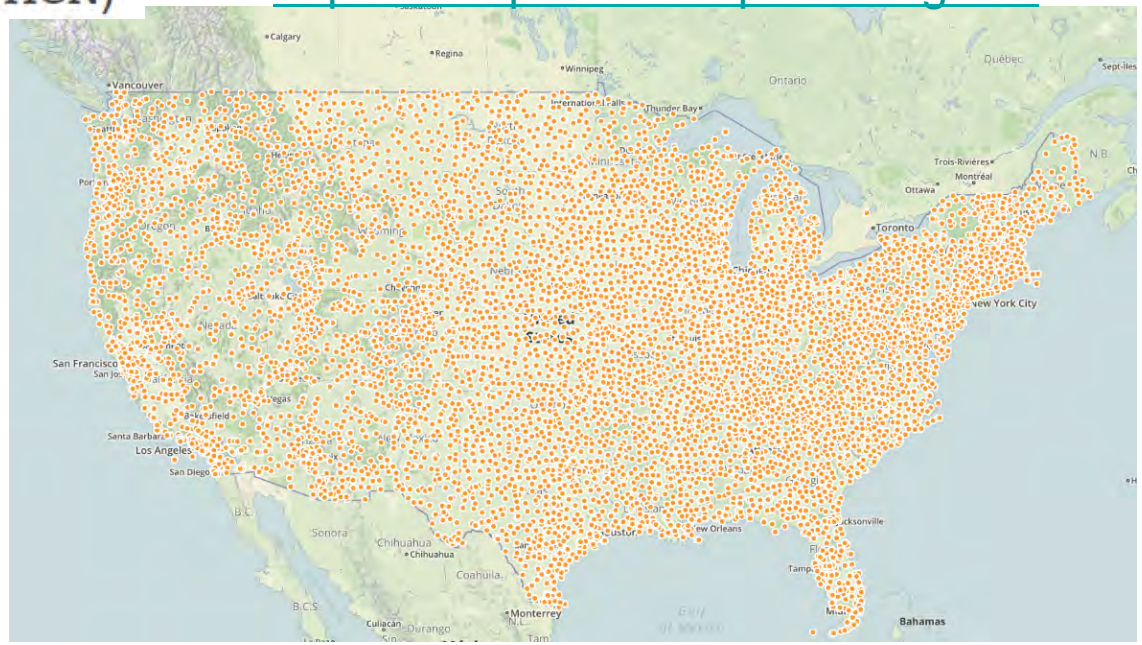
Global Historical Climatology Network (GHCN)

www.ncdc.noaa.gov/data-access/land-based-station-data/land-based-datasets/global-historical-climatology-network-ghcn

Future :

min/max from today to the end of the year

http://www.pestwatch.psu.edu/ghcn/



Modeling BMSB Phenology

http://bmsb.vmhost.psu.edu:8080/

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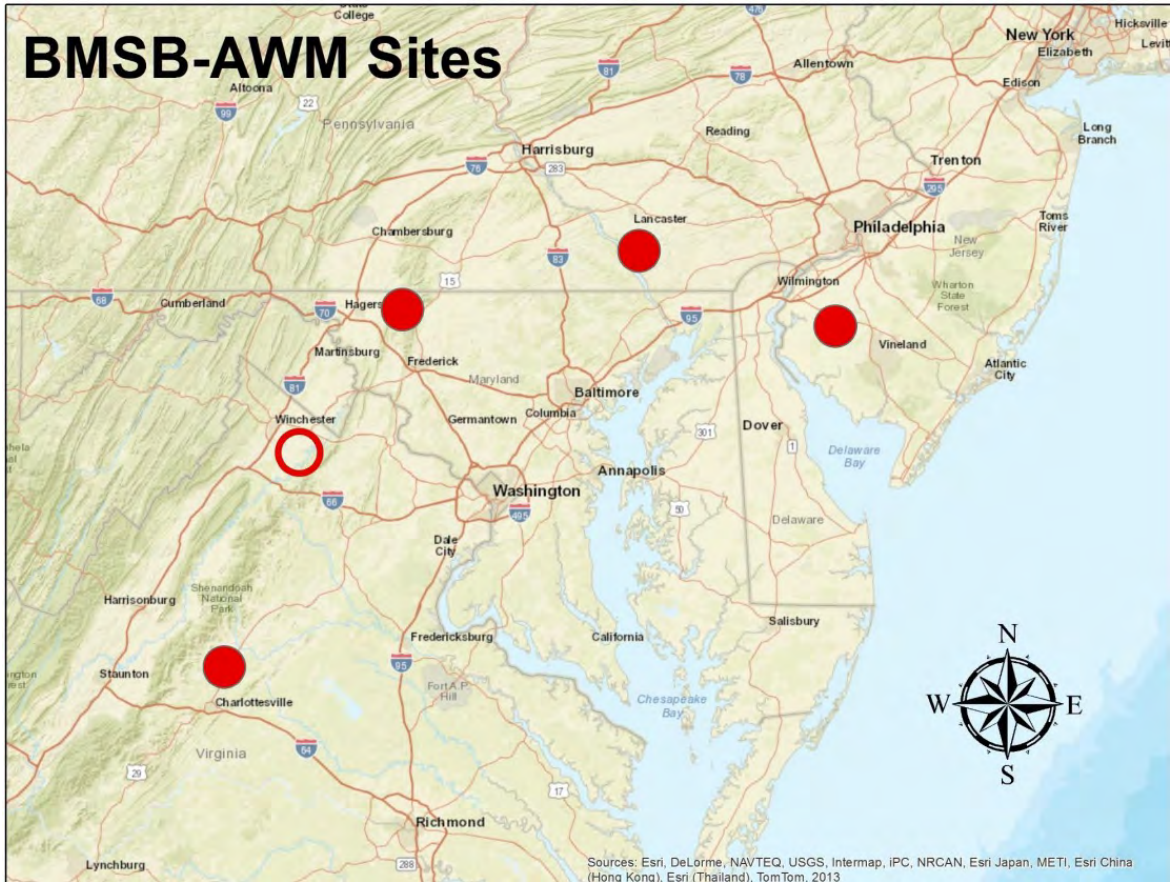
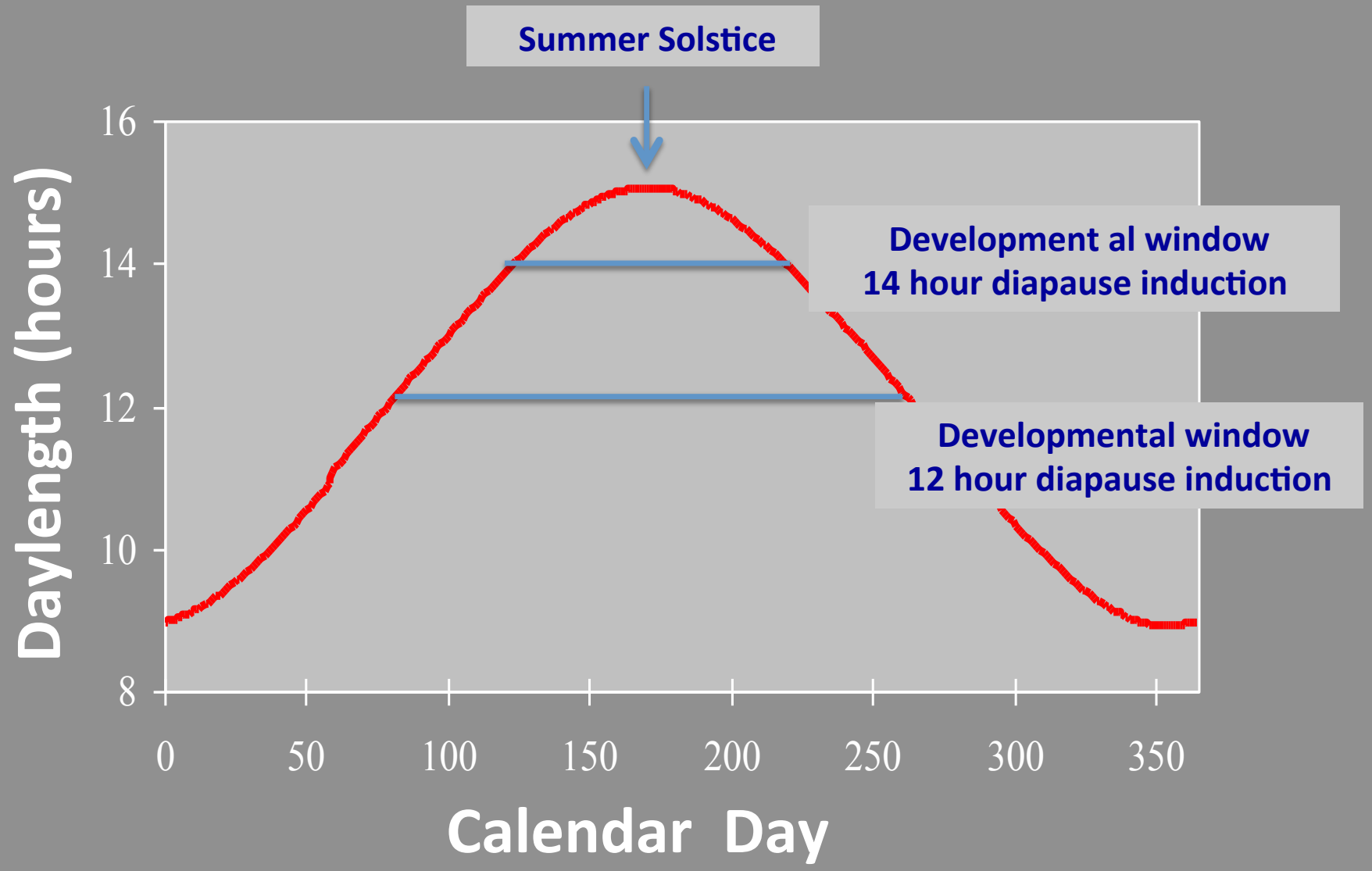
Build a Graphical User Interface

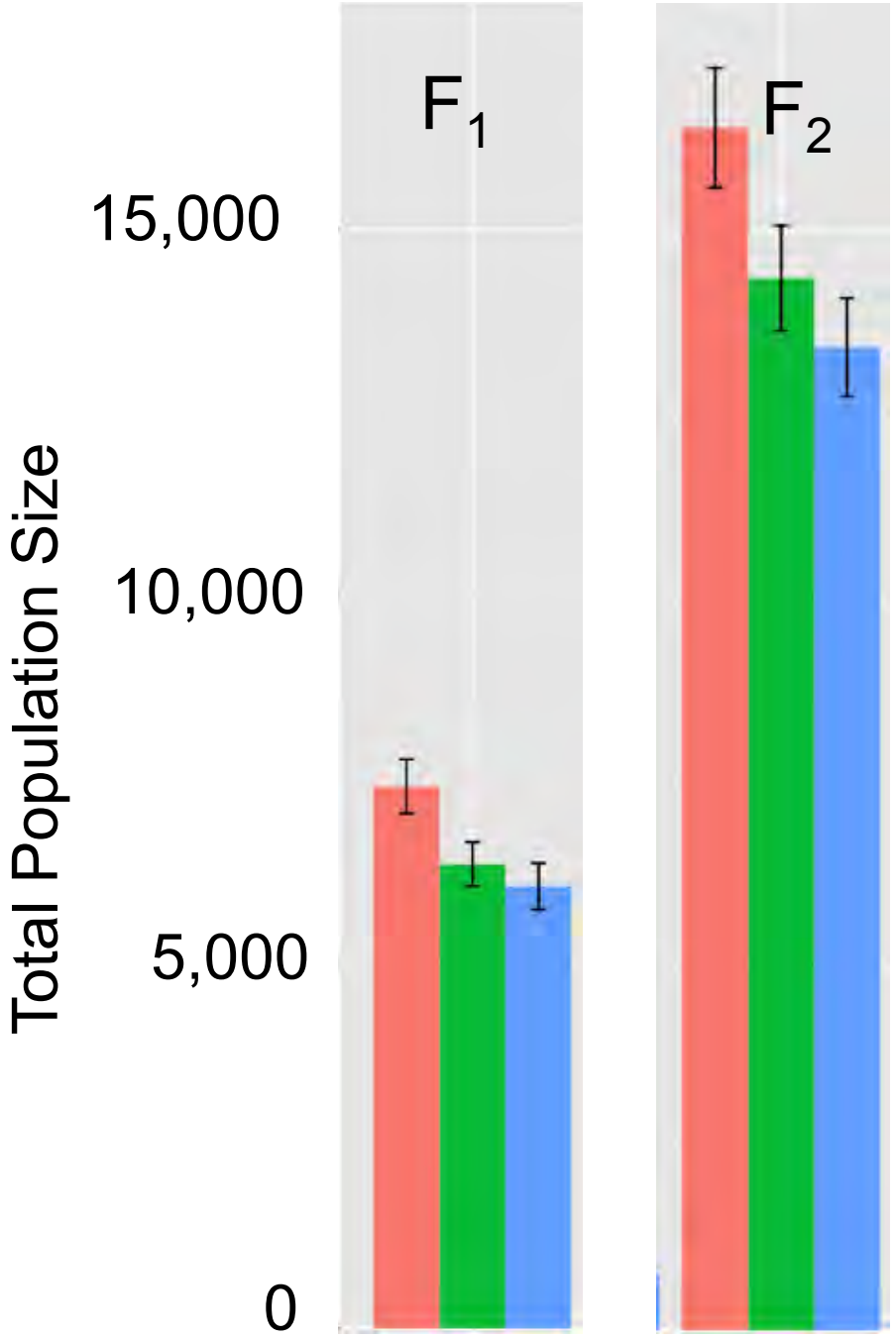
- For the Areawide BMSB Project
- Design it to be adaptable for other insects

PennState
Institute
for CyberScience



Photoperiod in Erie, PA (Latitude 42.08N)





Shorter photoperiod increases population

Allentown, PA, 2007

Photoperiod

13.5H

14H

14.5H

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Agent-based model of BMSB phenology, dyanmics, and voltinism under current climate conditions

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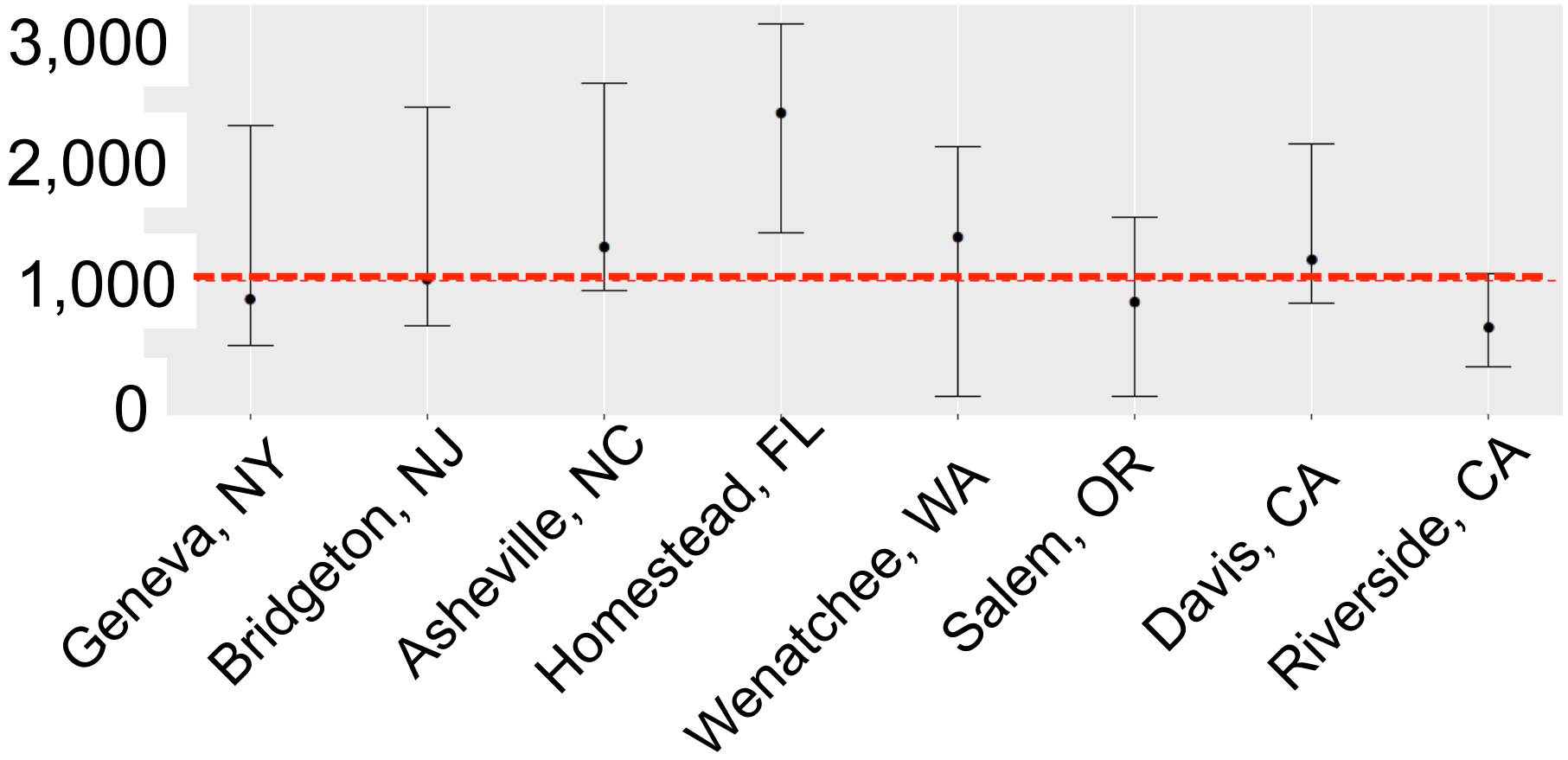
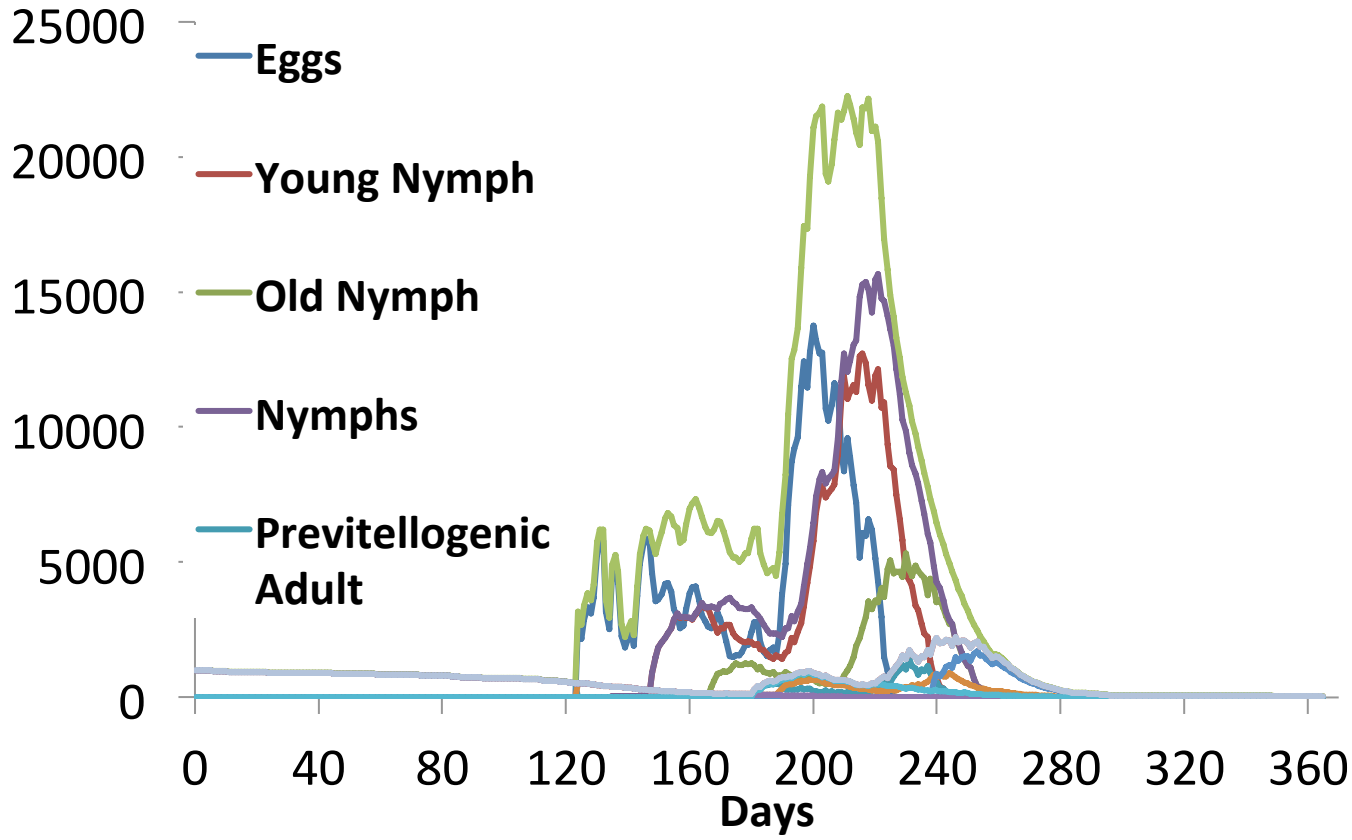
- ✓ Agent-based model for
  - Modeling phenology, dynamics and invasion risk
  - Species that overwinter as adults

- ✓ Diapause limits developmental window Selection pressure for relaxing this diapause constraint
- ✓ Abiotic interactions influence life stage synchrony and population growth potential
- ✓ All populations bivoltine, but variation in contribution of F_1 versus F_2 adults to the OW adults

Final Population (mean + SE)



Initial Population = 1,000
100 Simulations/Year
10 years:2005-2015


25000
20000
15000
10000
5000
0
Eggs
Young Nymph
Old Nymph
Nymphs
Previtellogenic Adult
0
40
80
120
160
200
240
280
320
360
Days

Formerly the National Climatic Data Center (NCDC)... more about NCEI »

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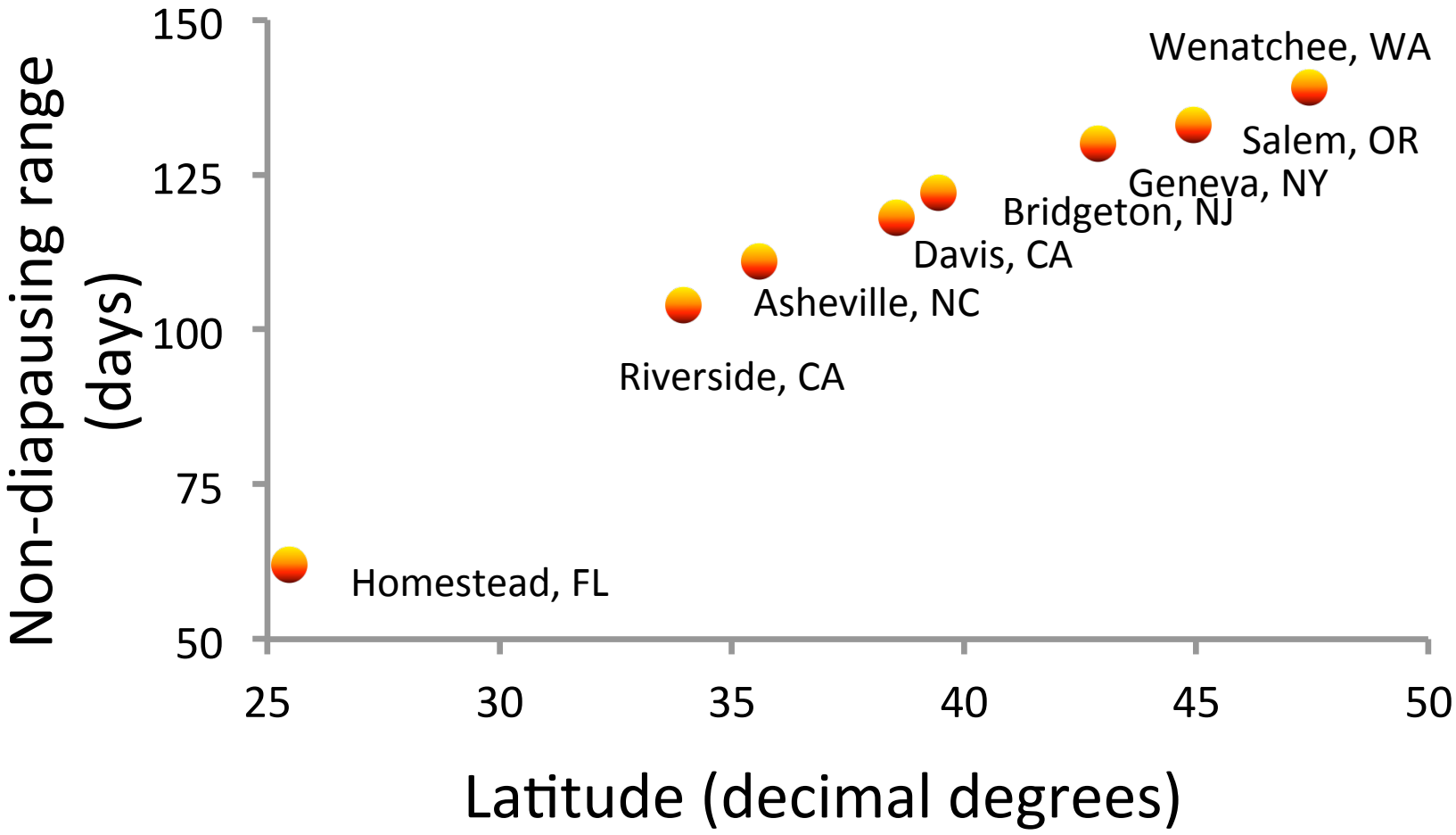
Quick Links

Global Historical Climatology Network (GHCN)

Photo: N. Sloff

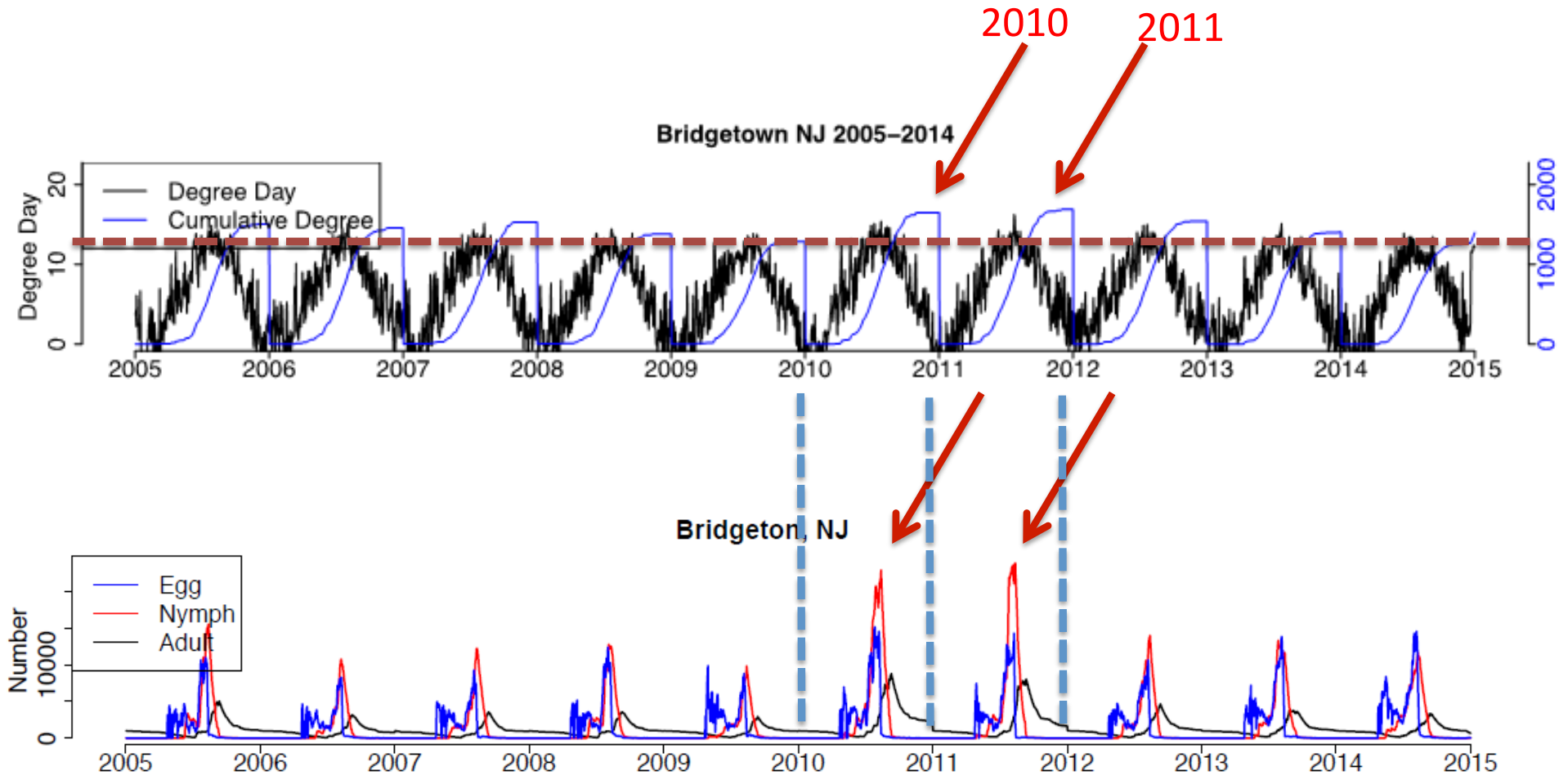
- ✓ How much of each generation
- ✓ Who overwinters
- ✓ Can we predict when F_1 emerge

Non-diapausing range at 13.5 hour photoperiod



Literature reports diapause from 13.5 to 14.75 hr

2010 and 2011 had high damage rates



Successfully Simulated
Strongly Overlapping Life Stages