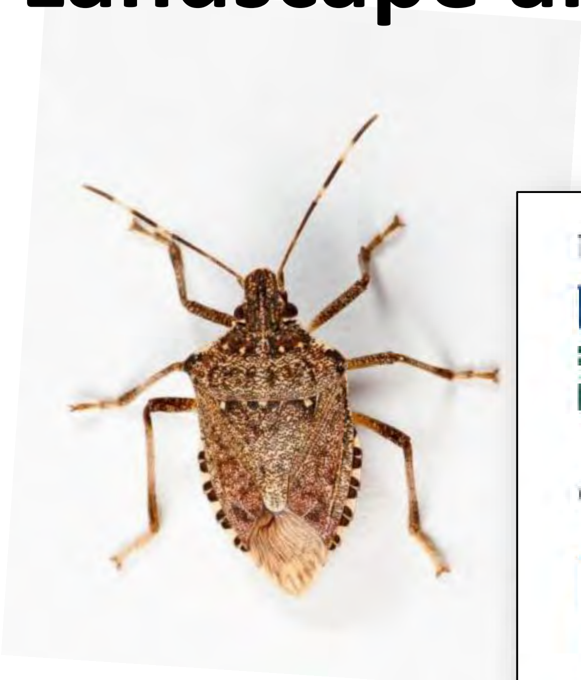
Objective 1 – Voltinism, Dispersal, Landscape and Temporal Risk Factors



Funding

USDA

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Collaborating Institutions

University of Delaware

ARS

Penn State

Rutgers, The State University of New Jersey

Northeastern IPM Center

Washington State University

Cornell University

University of Maryland

Virginia Tech

OSU Oregon State University

NC State University

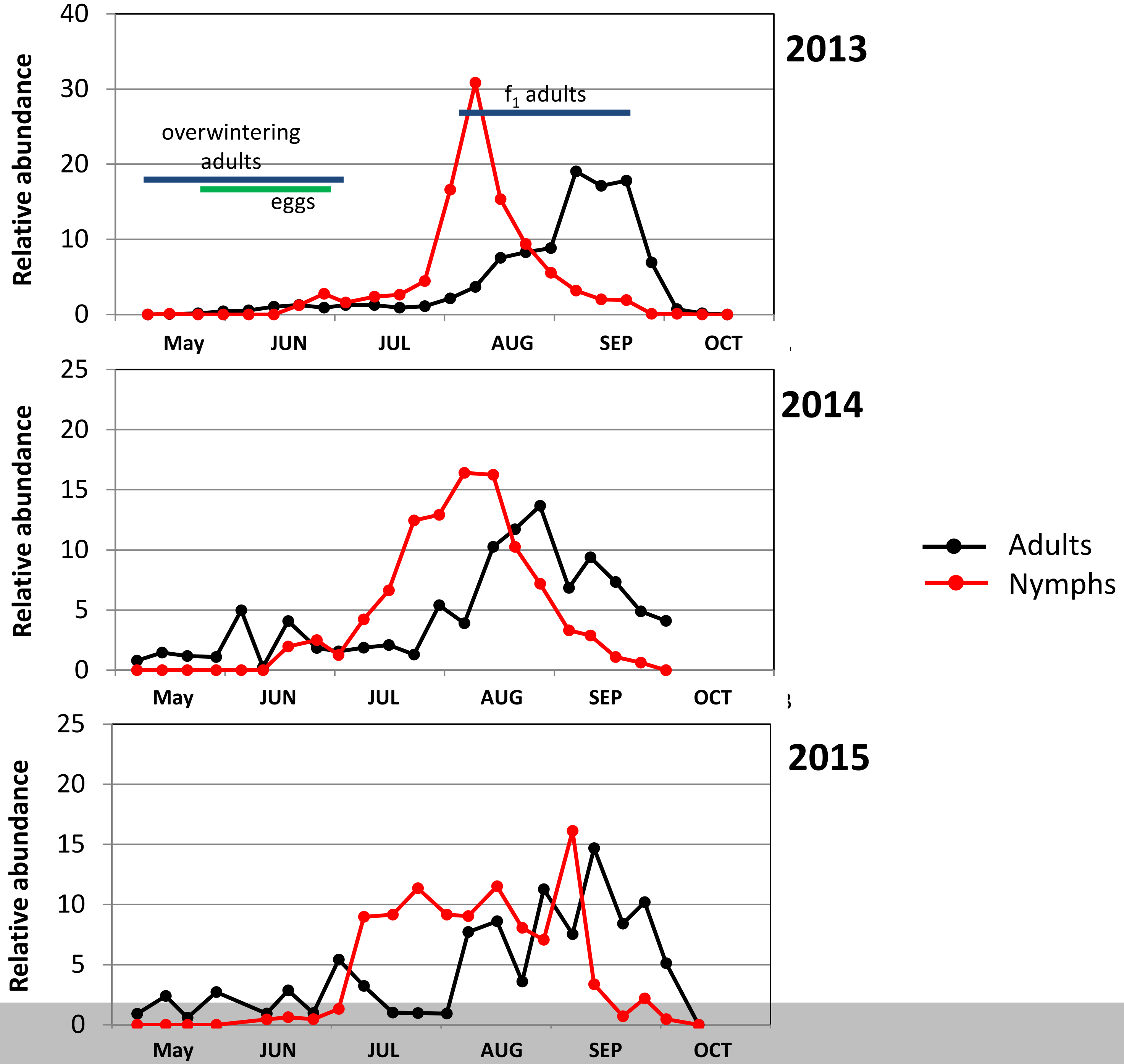
StopBMSB.org

Development and Movement

- 1.1.1 - Determine phenology and voltinism characteristics of BMSB
- 1.1.2 - Movement to and from overwintering sites and overwintering survivorship
- 1.3.2 - Determine BMSB invasion patterns into new habitats
- 1.3.3 - Identify movement and dispersal patterns in peach and apple orchards
  - 2015 populations too low
- 1.4 - Identify landscape and temporal risk factors associated with BMSB on crops and in adjacent ecosystems.

Shearer, Agnello, Jentsch, Wiman, Bergh, Shrewsbury, Hamilton, Flesicher, Walgenbach, Morrison, Rice, Tooker, Kuhar, Dively, Leskey, Nielsen

Seasonality in NC



What Do We Use as a Biofix?

- When development in the field begins
- Critical for determining the number of generations
- Development takes 538 DD_{14} *(Nielsen et al. 2008*), 588 $DD_{12.2}$ *(Haye et al. 2014)*
  - Females need additional time 60-147 DD to become mature
- Asian literature suggests 13.5 – 14.75h of daylength
- Previous biofixes January 1 – May 30

What Do We Use as a Biofix?

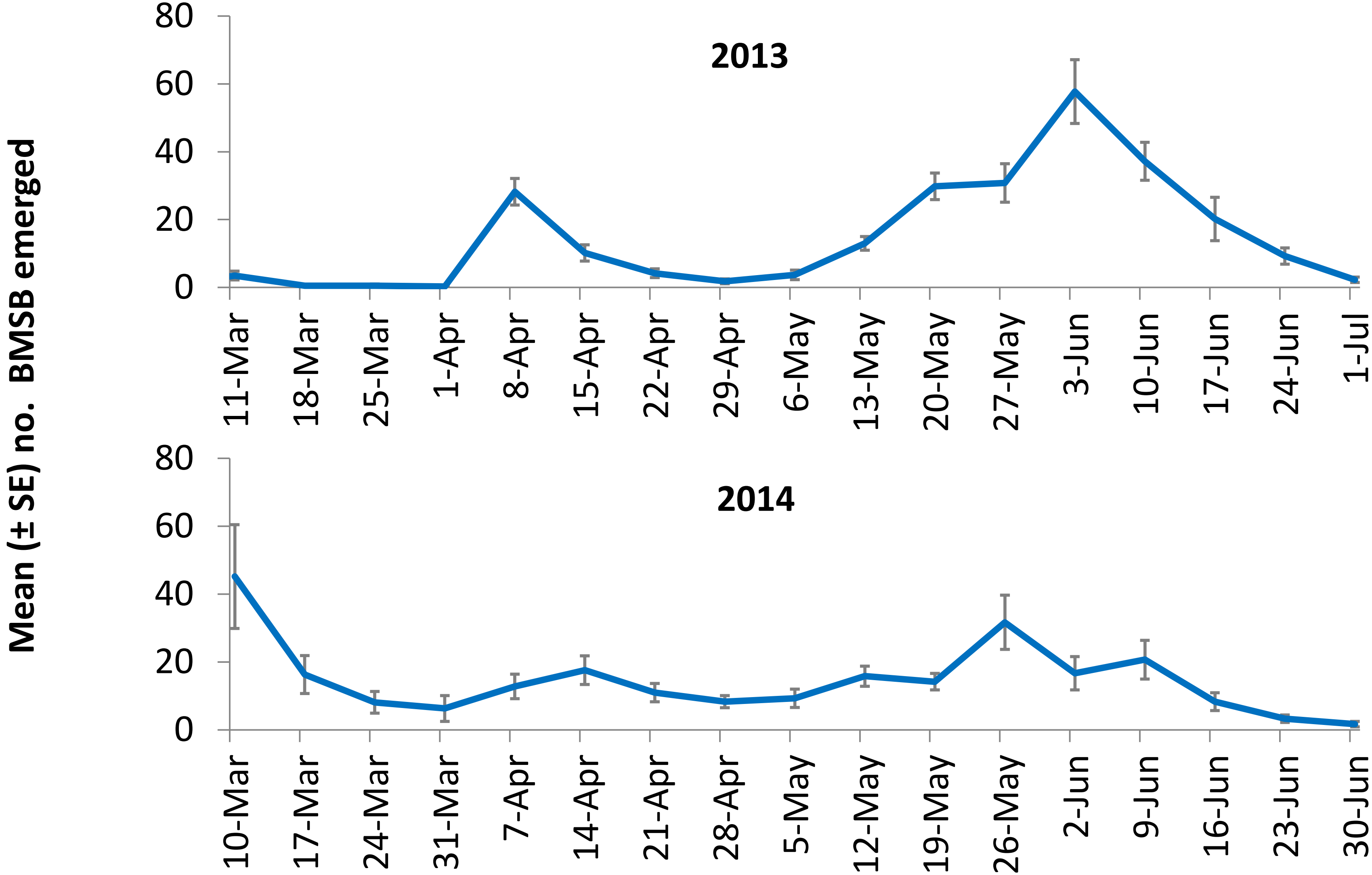
Multiple studies have been used to investigate this

- Emergence from overwintering cages
- Laboratory trials identifying first oviposition under various photoperiods
- Voltinism cages
- Reproductive seasonality
- Agent-based phenology model

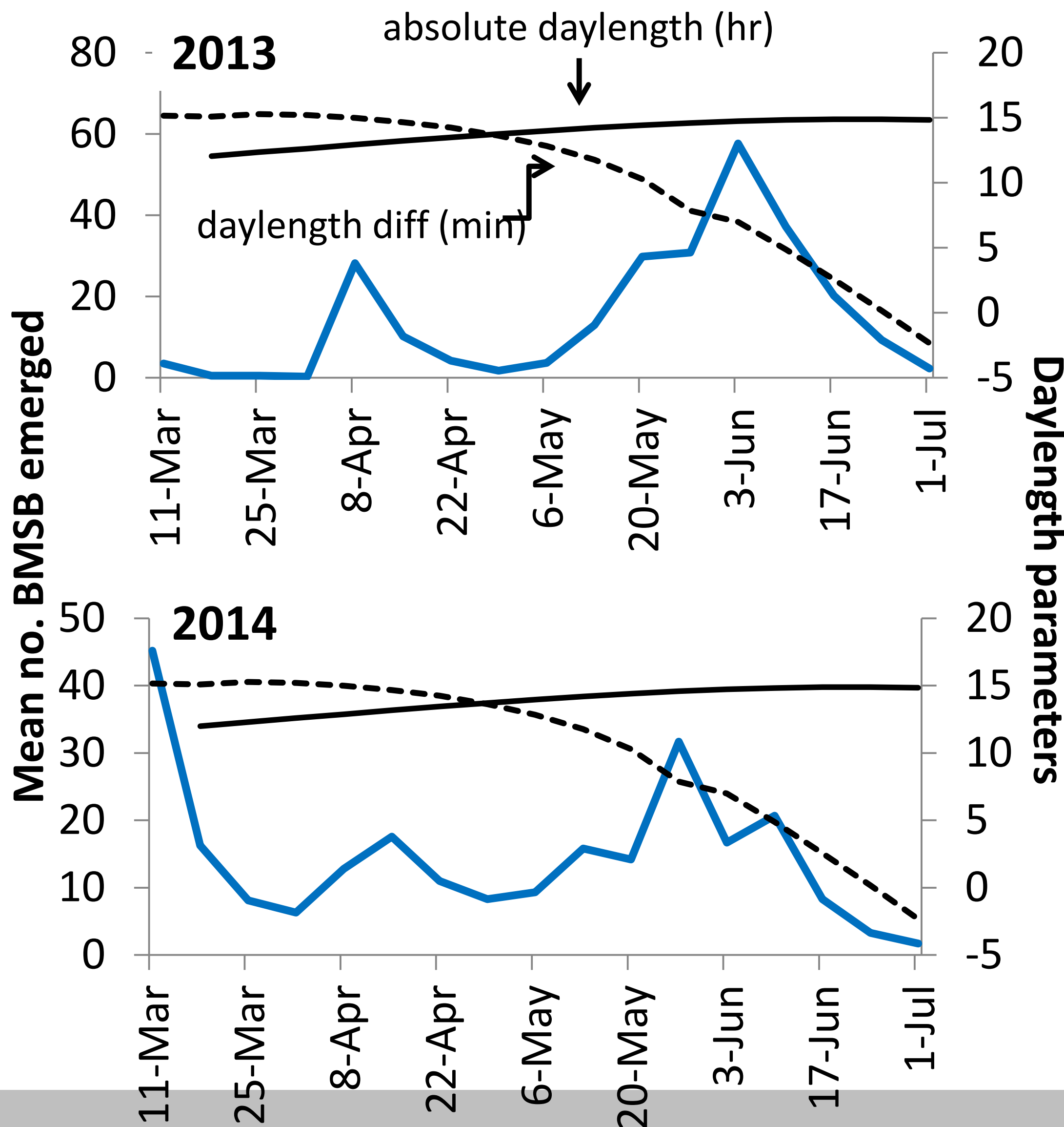
Emergence from Overwintering Cages

- Shelters deployed in pairs within protective domes at six woodland sites in late February
- Internal and external temperature sensors

Mean no. BMSB emerged per week



Emergence in Relation to Photoperiod



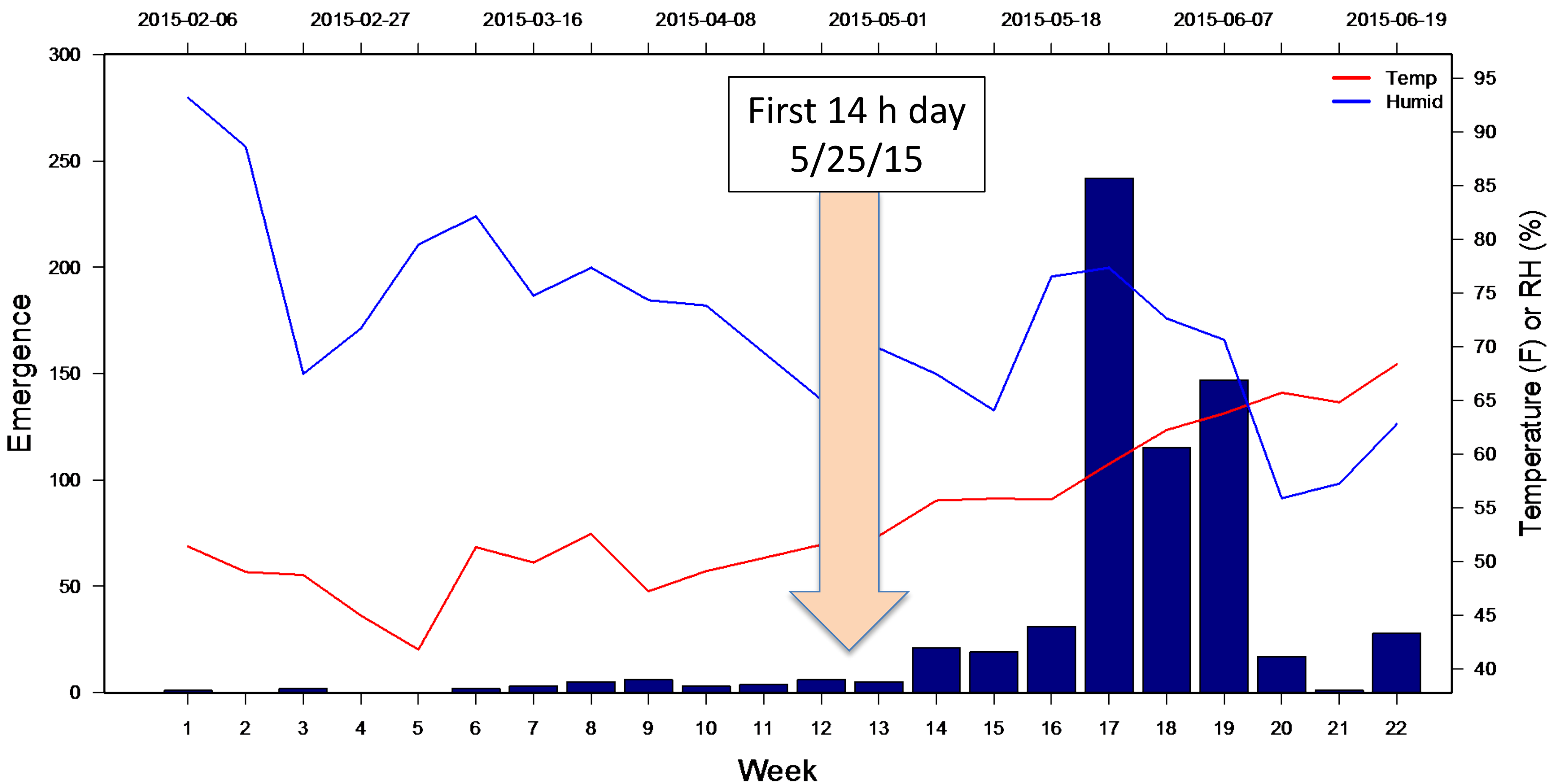
Kendall's Tau Correlation Coefficient:
Entire period

Year	Tau	P
2013	-0.4207	**< 0.019**
2014	0.0969	= 0.592
Both	-0.1652	= 0.176

Kendall's Tau Correlation Coefficient:
May 26 – July 1

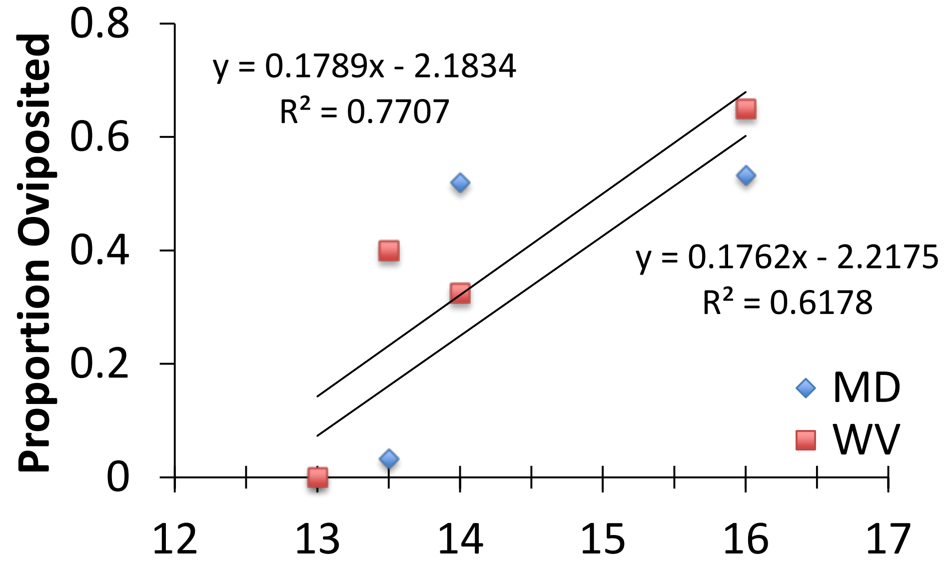
Year	Tau	P
2013	0.7333	**< 0.039**
2014	0.8667	**= 0.015**
Both	0.6992	**< 0.002**

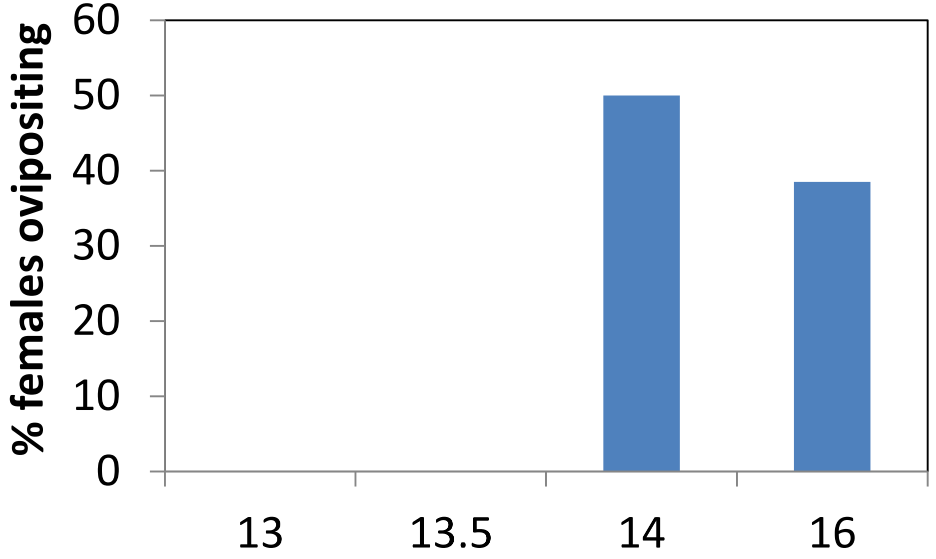
Emergence study results - OR



Laboratory Studies NJ and NC

- Overwintered adults held at 25°C at different photoperiods
- Time to egg laying monitored
- NC and NJ (MD and WV bugs)
- No eggs laid at 13.0h daylength
- **Diapause termination cue 13.5-14h**





Nielsen – Rutgers
Walgenbach - NCSU

2015 New York BMSB Voltinism Results Hudson Valley and Western NY

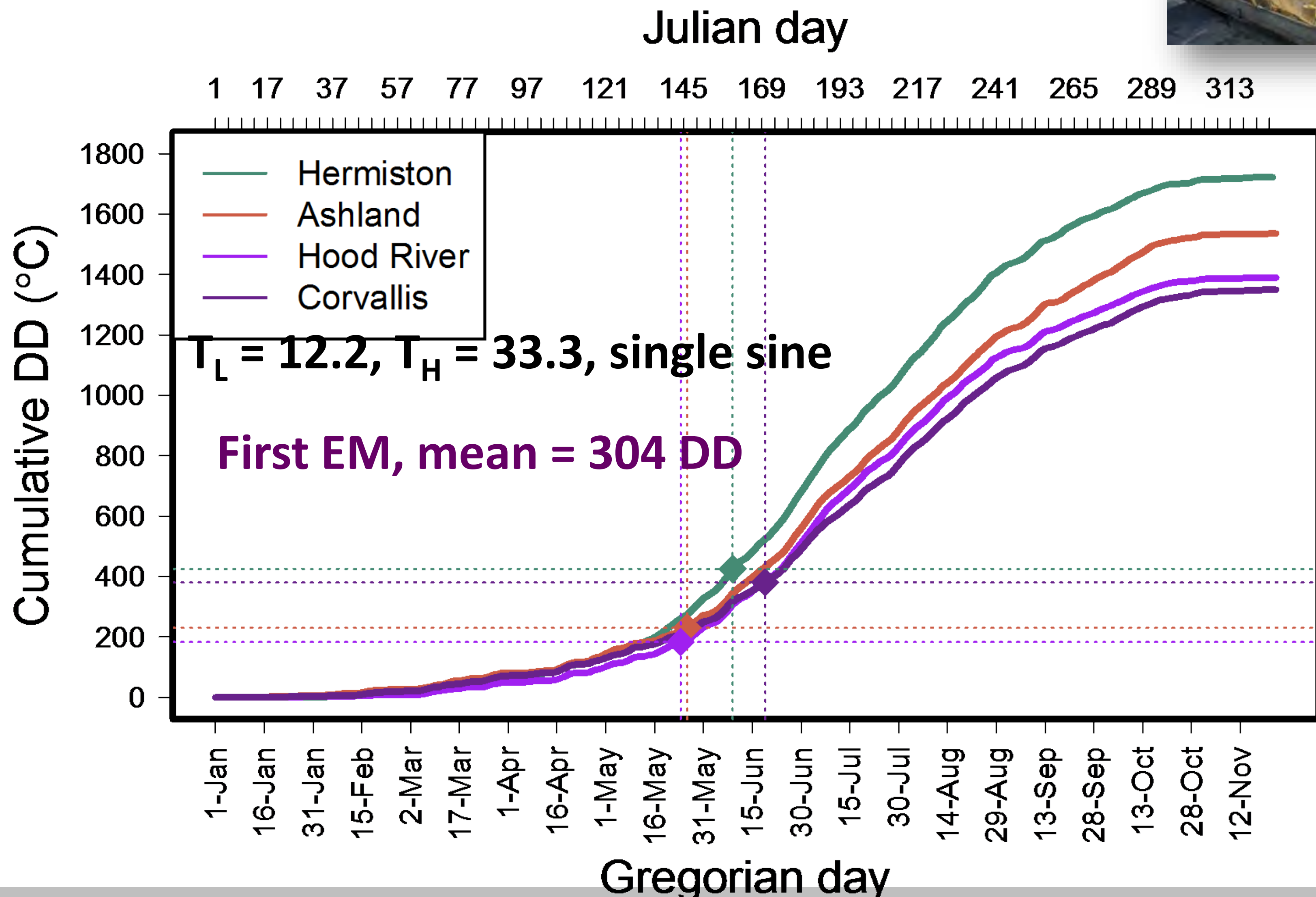
Events		Date	DD_{50F}
25M / 25F to outdoor voltinism tent		14 May*	
1st egg cluster		28 May	0.0
1st instar		3 June	36.0
2nd instar		15 June	253.0
3rd instar		22 June	396.4
4th instar		29 June	513.8
5th instar	*(7th July Collapse)*	*24 July (wild)*	*1062.3*
1st adult		12 August	1517.4
No mating or oviposition observed			

*400 overwintering BMSB adults arrived 13 May, 2015 LabServices; Hamburg, PA,

Cornell University College of Agriculture and Life Sciences

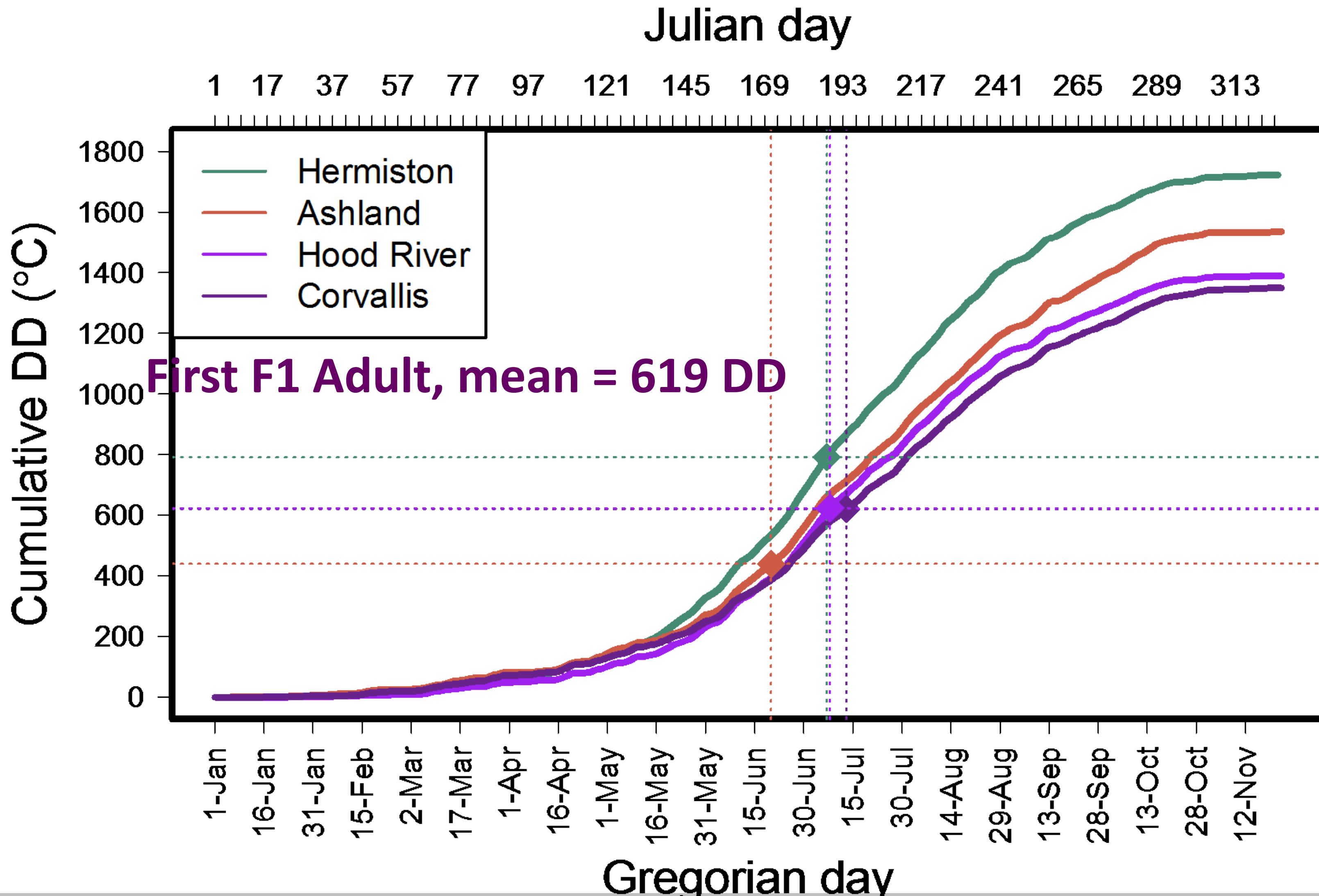
Hudson Valley Research Laboratory

Voltinism Cages - OR



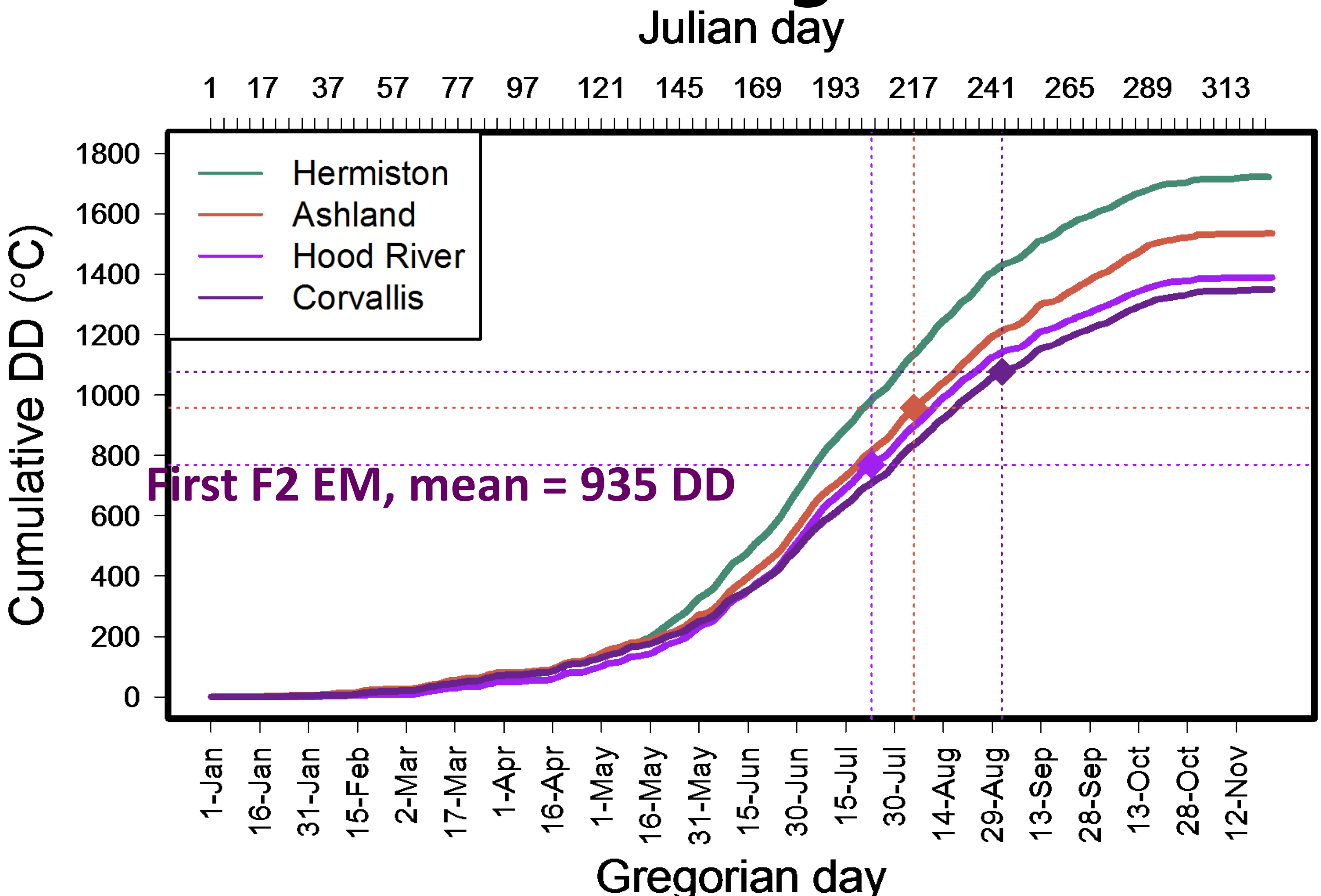
Wiman, Shearer, Davis, Hilton, Rondon

Voltinism Cages - OR



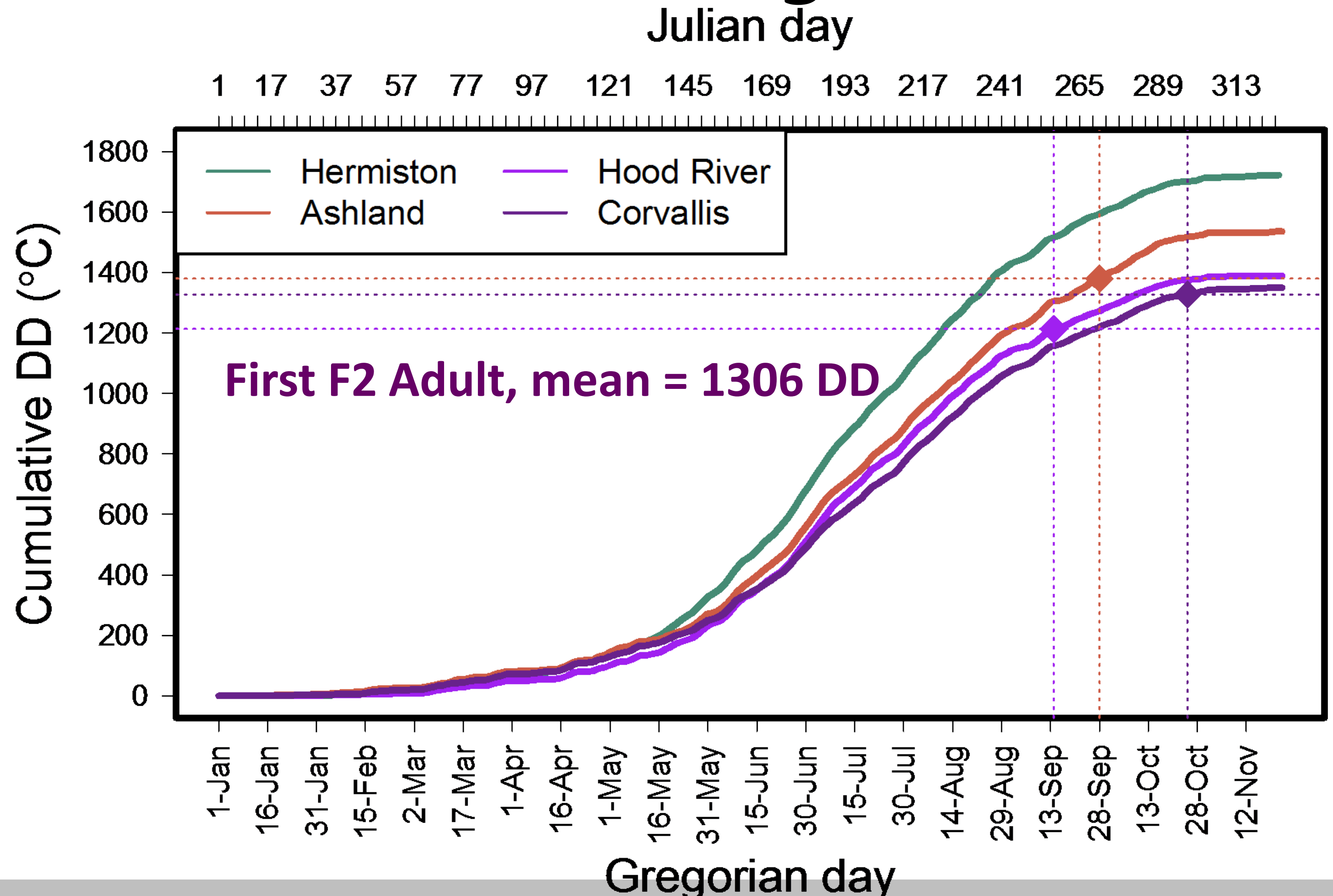
Wiman, Shearer, Davis, Hilton, Rondon

Voltinism Cages - OR



Wiman, Shearer, Davis, Hilton, Rondon

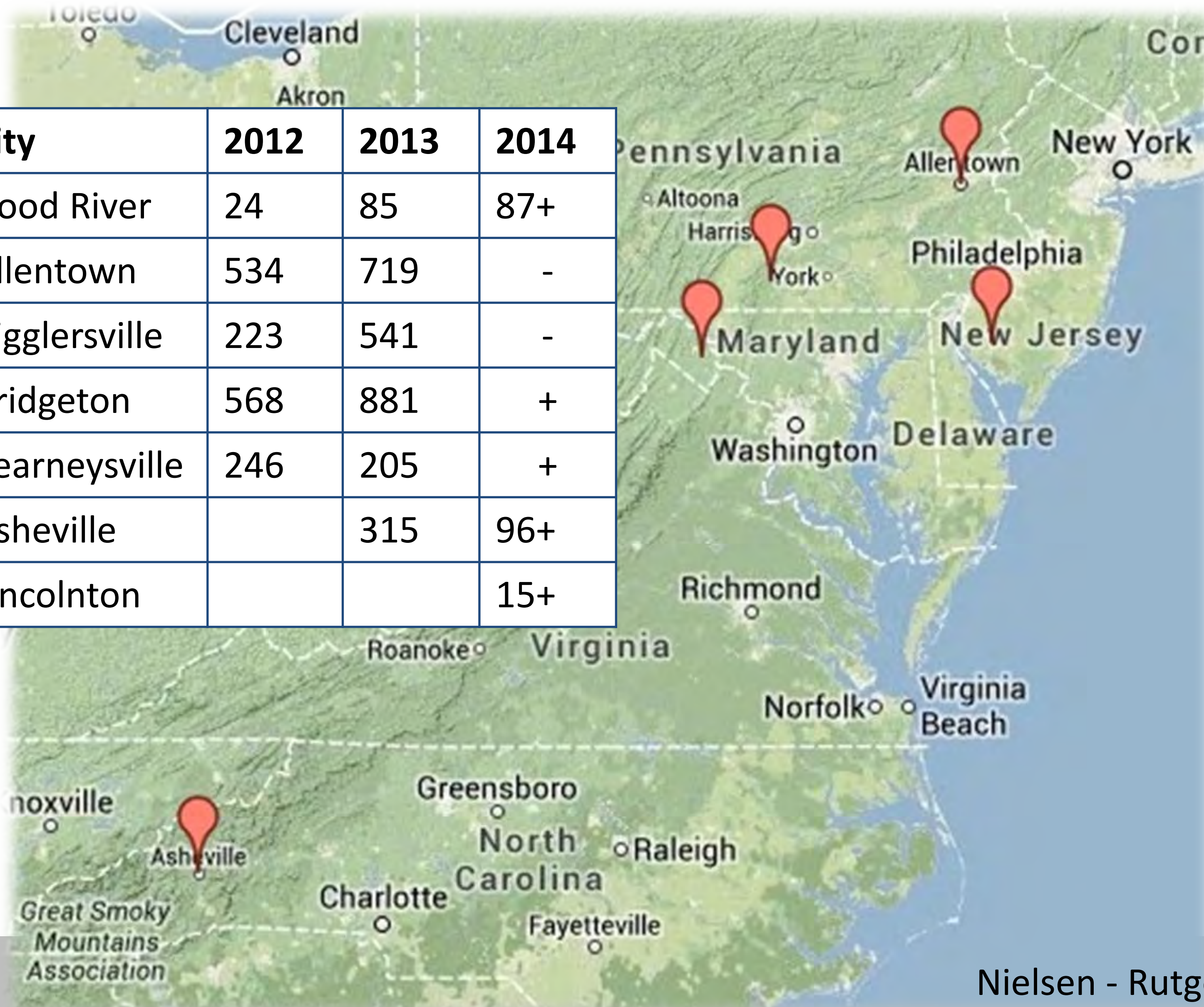
Voltinism Cages - OR

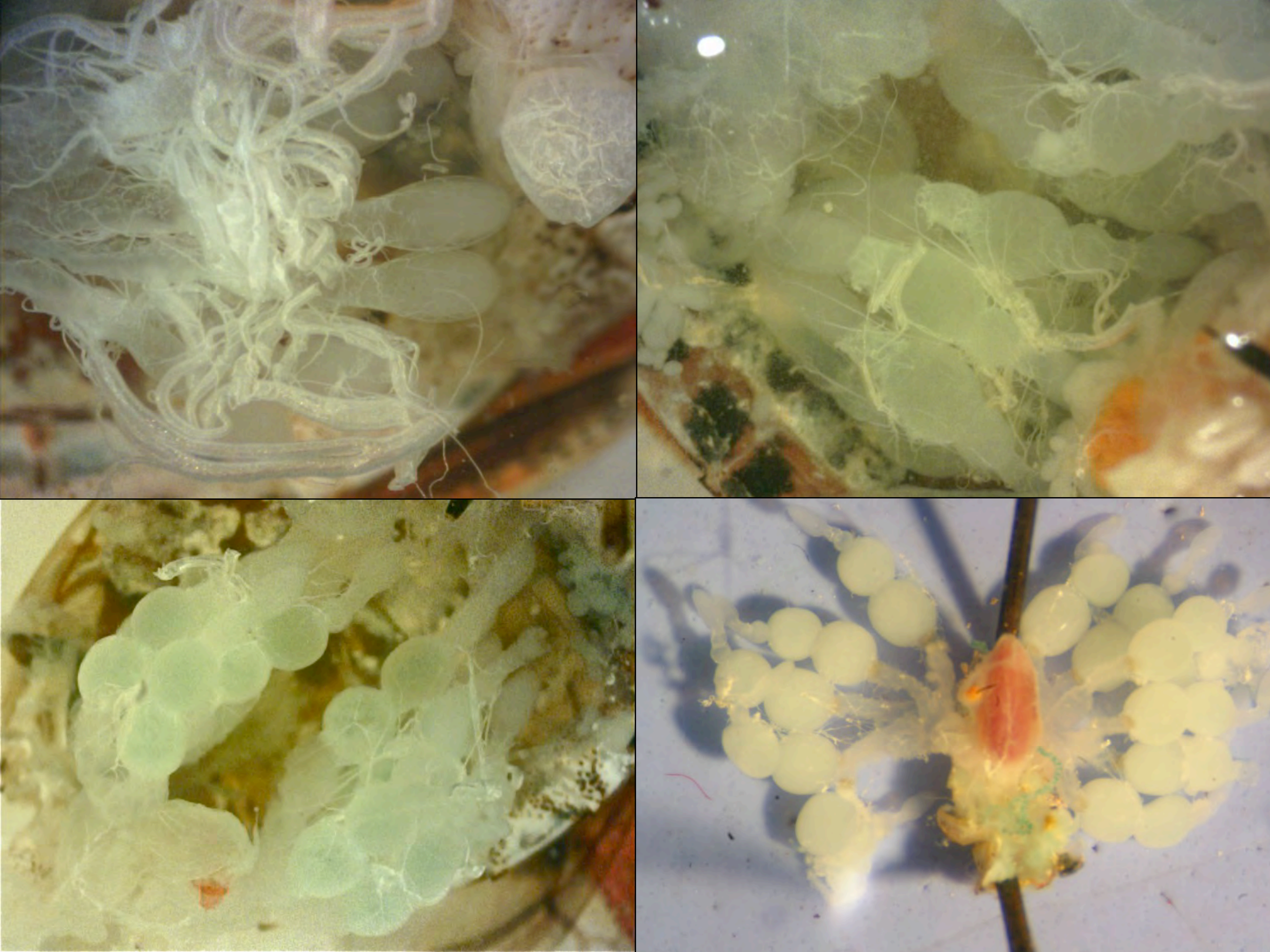


Wiman, Shearer, Davis, Hilton, Rondon

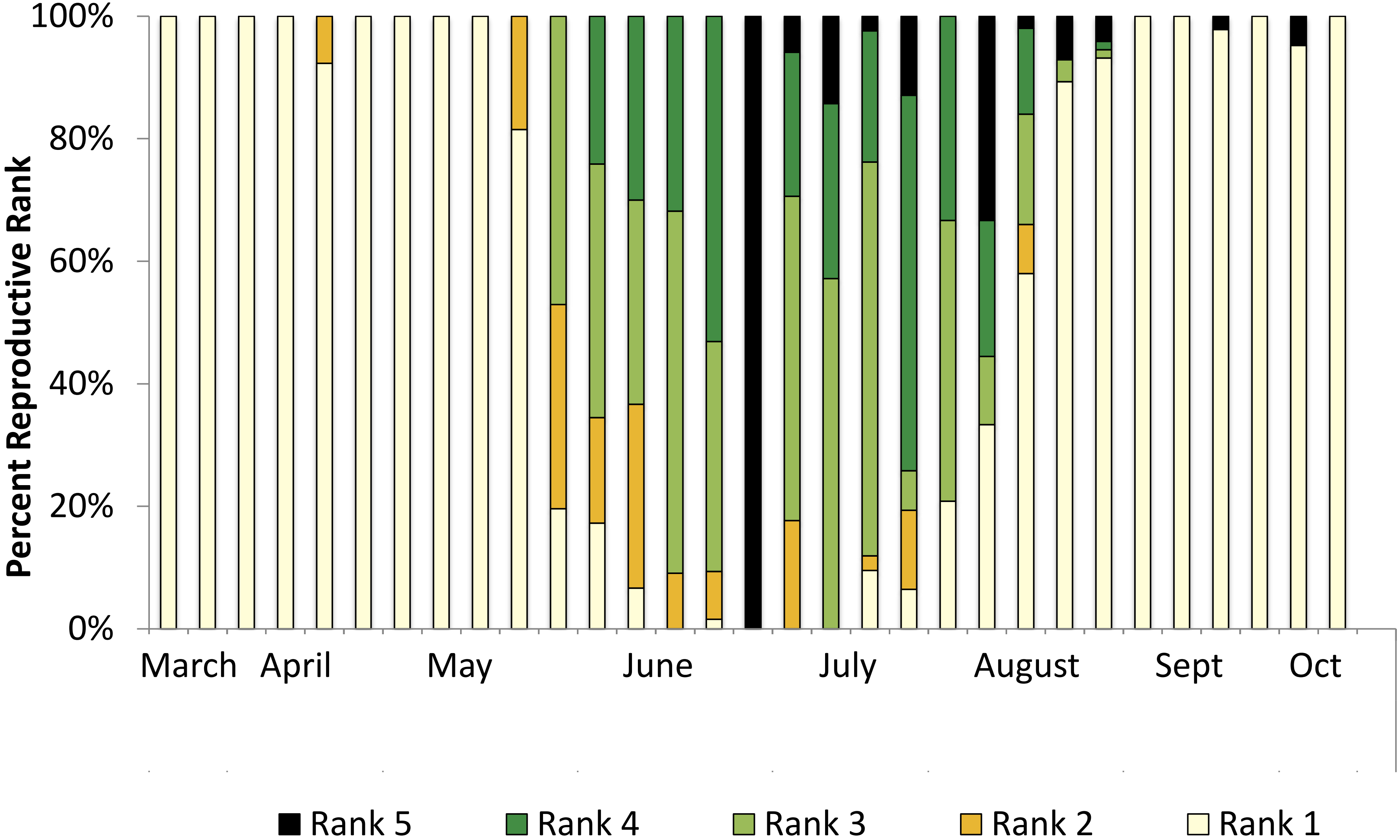
Female Reproductive Phenology

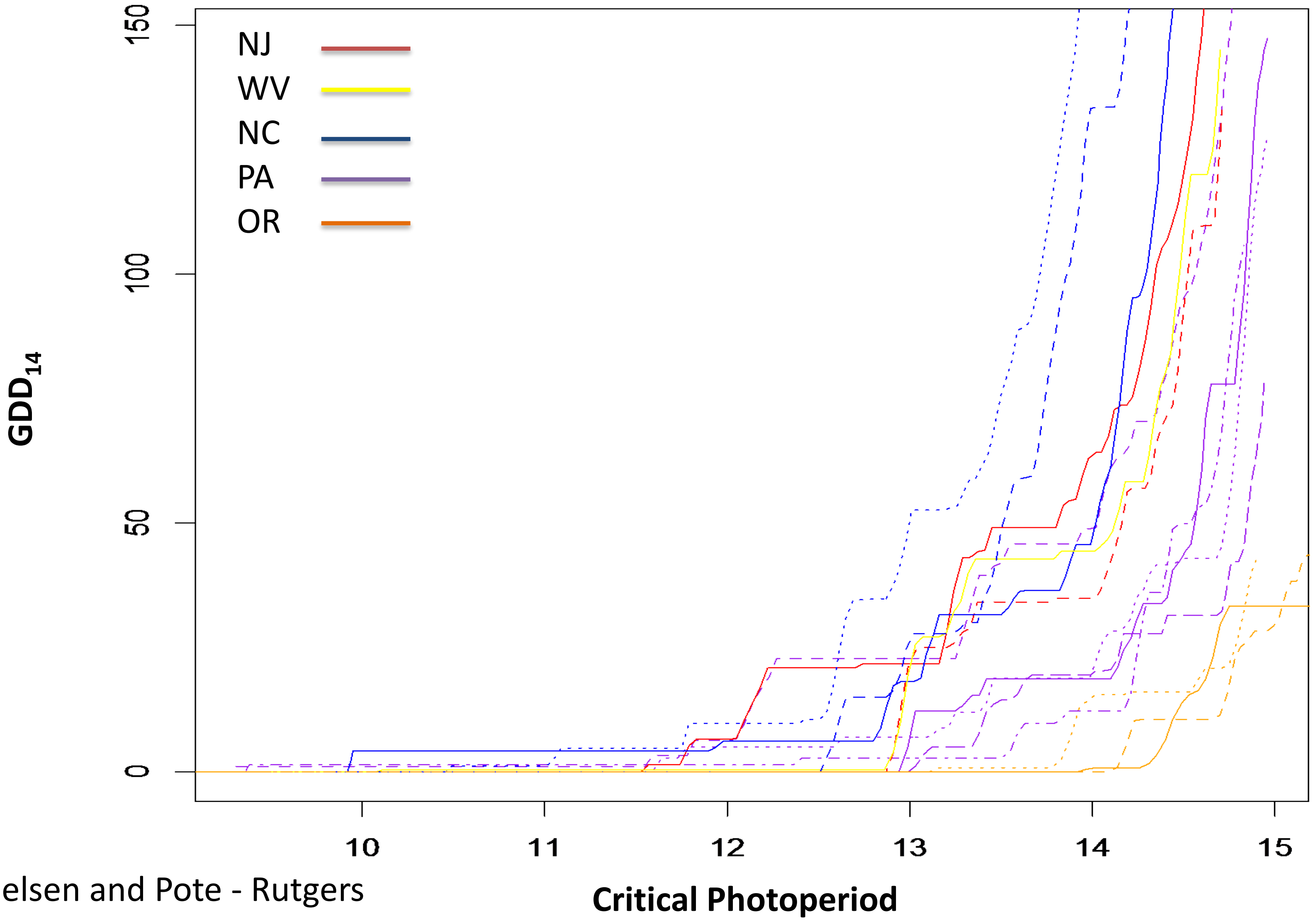
State	City	2012	2013	2014
OR	Hood River	24	85	87+
PA	Allentown	534	719	-
PA	Bigglersville	223	541	-
NJ	Bridgeton	568	881	+
WV	Kearneysville	246	205	+
NC	Asheville		315	96+
NC	Lincolnton			15+





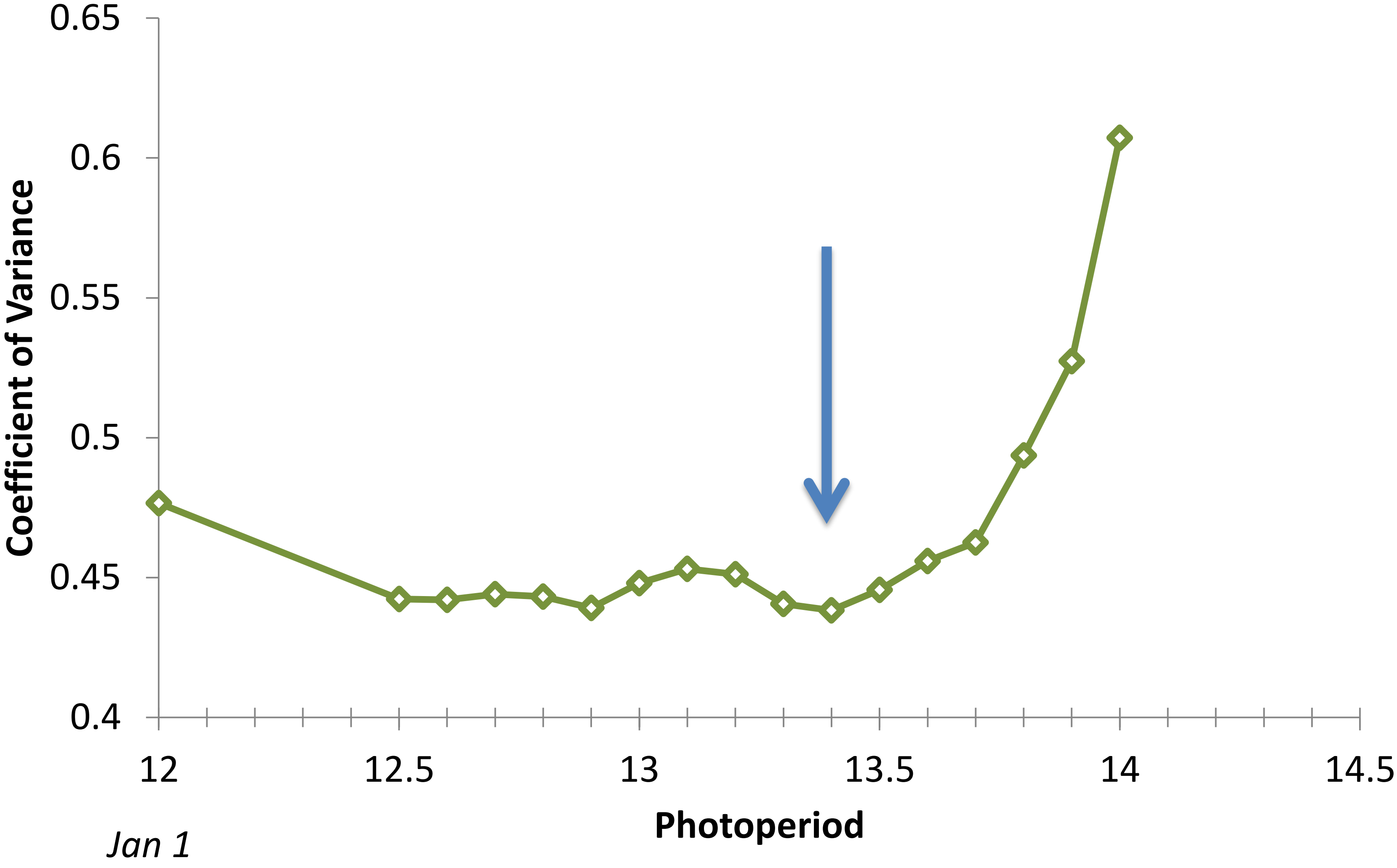
Bridgeton, NJ 2014

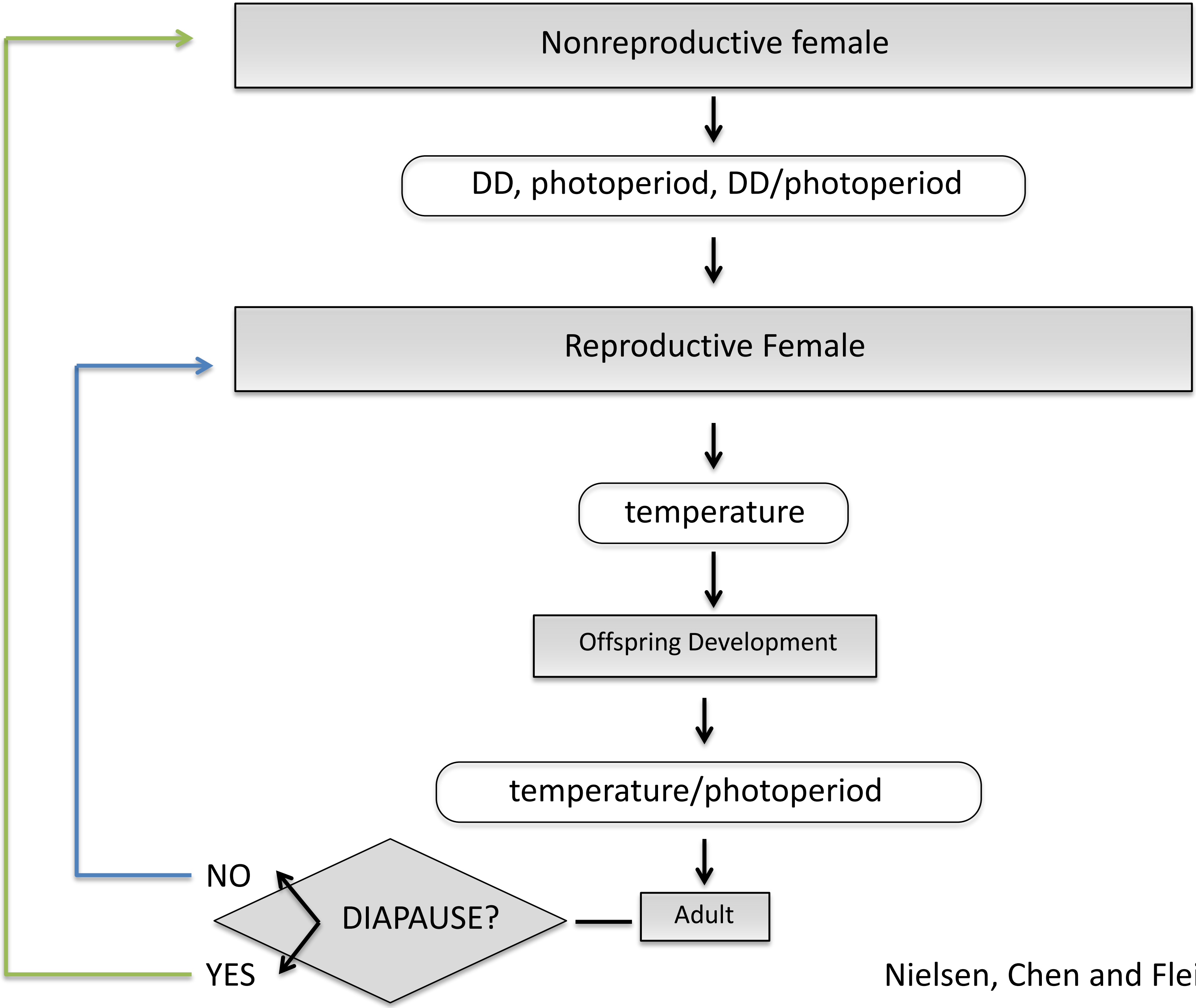




Nielsen and Pote - Rutgers

Biofix Predictions

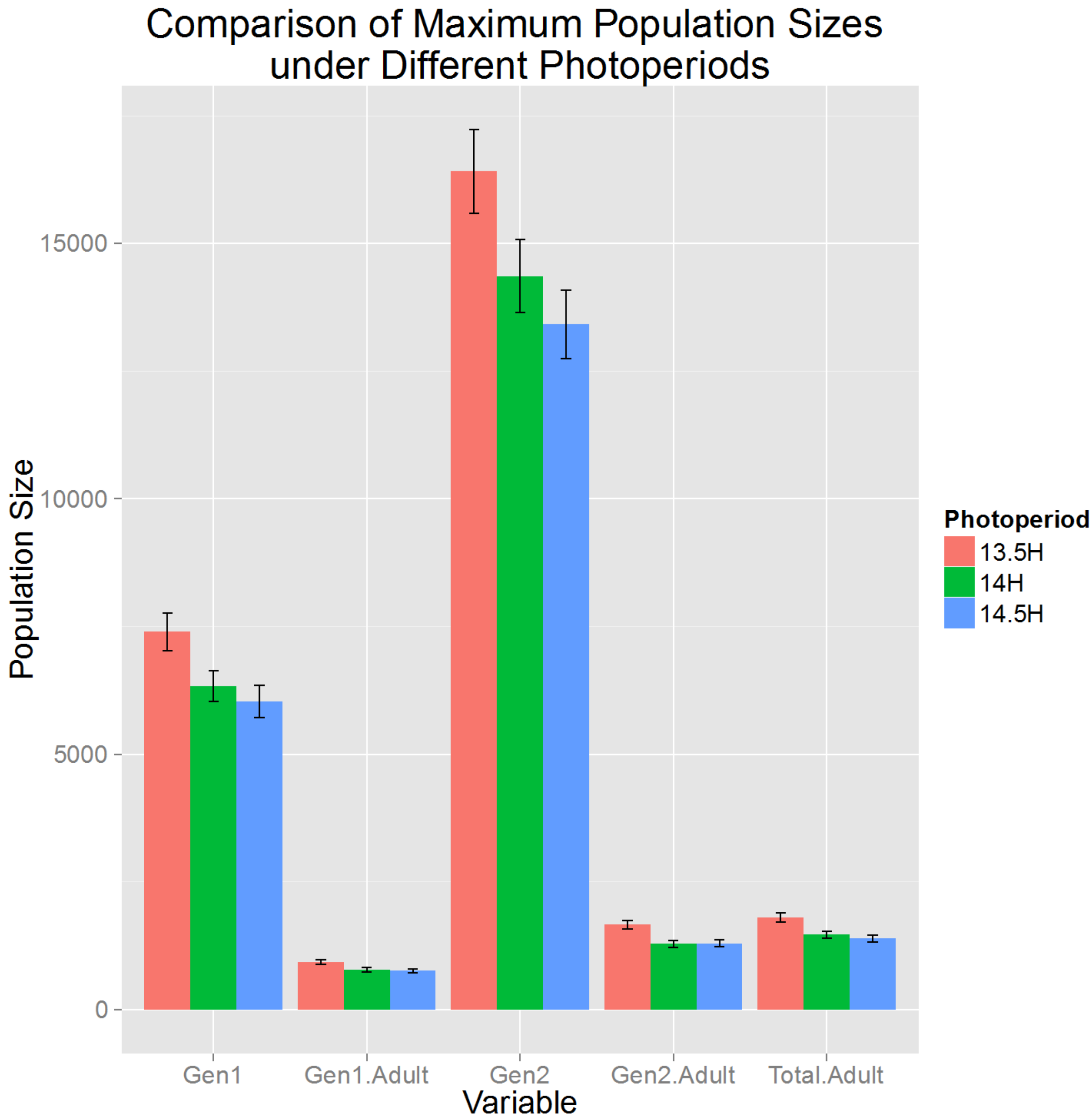




Nielsen, Chen and Fleischer

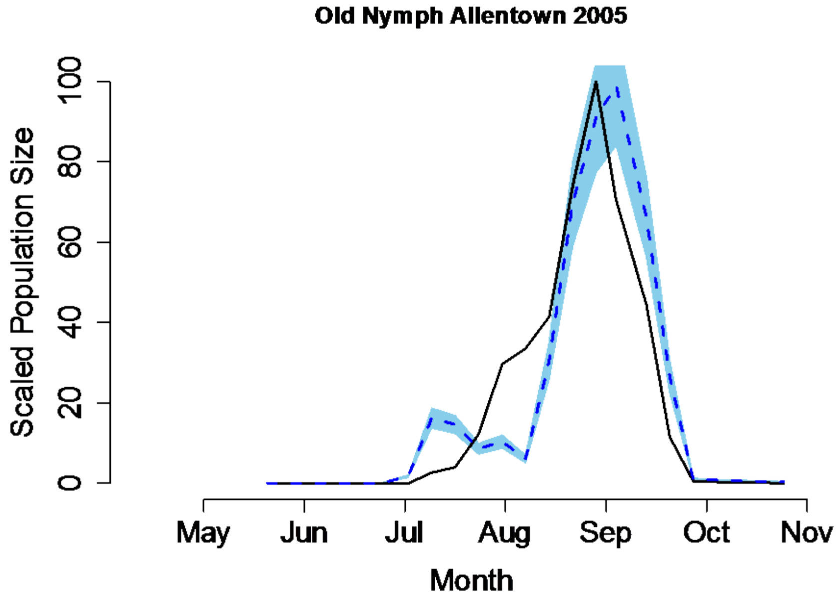
Phenology Model

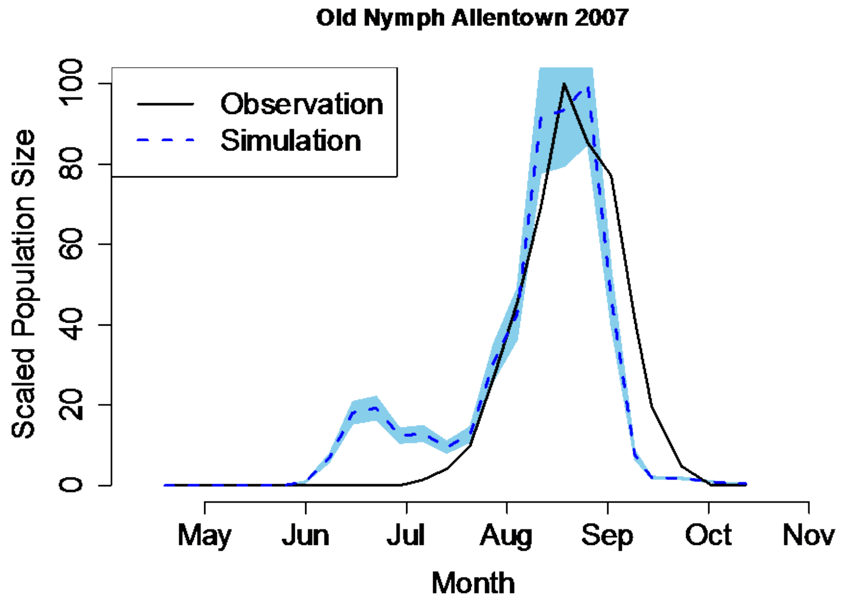
- Individual, stage-specific variability in development rate and mortality
- Interaction between contrasting environmental factors
  - Southern area has higher DD accumulation but shorter total development period bracketed by the 13.5h critical photoperiod
- Comprehensive consideration of physiology, temperature, photoperiod, phenology, and population



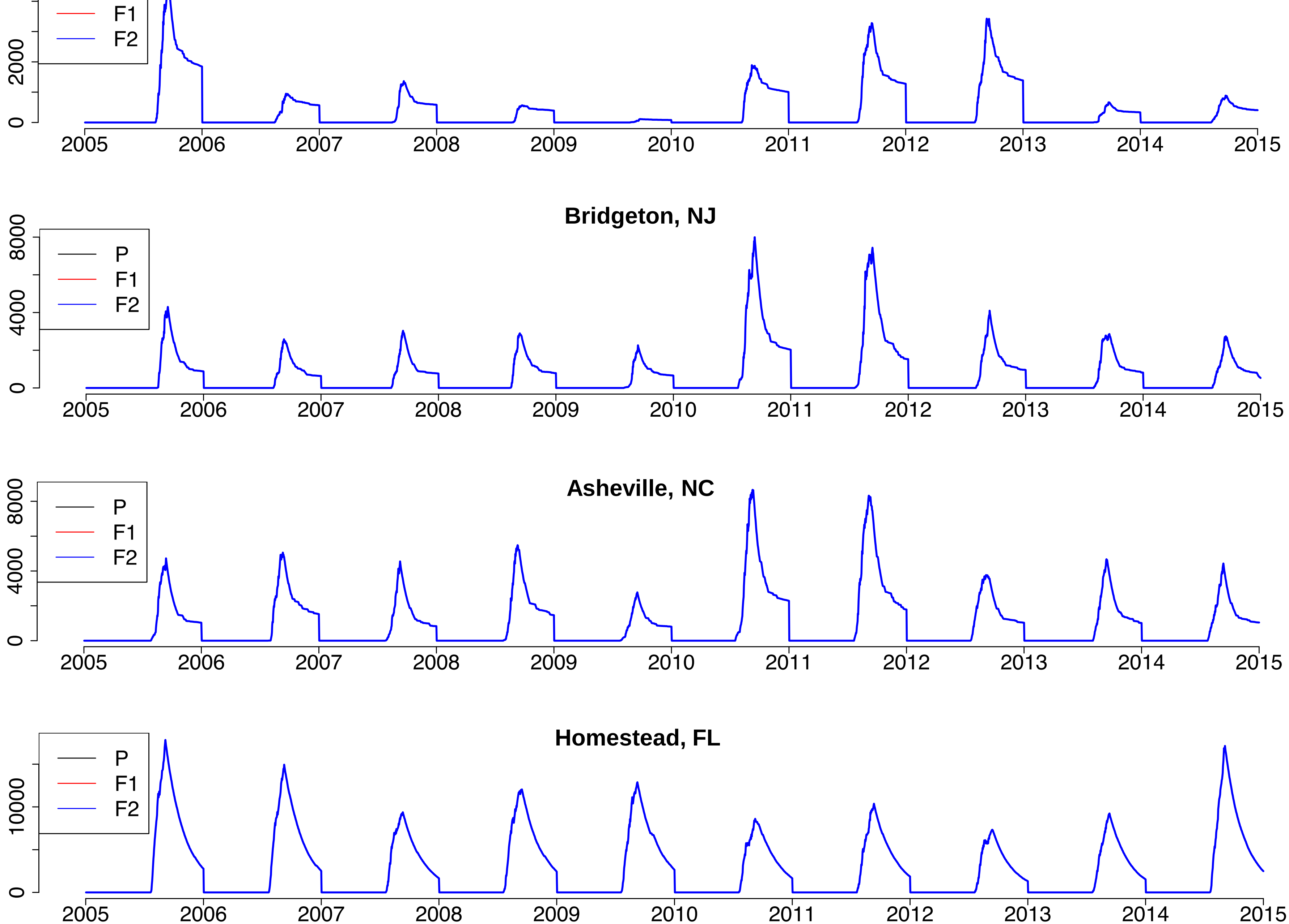
Comparison of Maximum Population Sizes
under Different Photoperiods
Population Size
15000
10000
5000
0
Gen1
Gen1.Adult
Gen2
Gen2.Adult
Total.Adult
Variable
Photoperiod
13.5H
14H
14.5H

Validation of Model

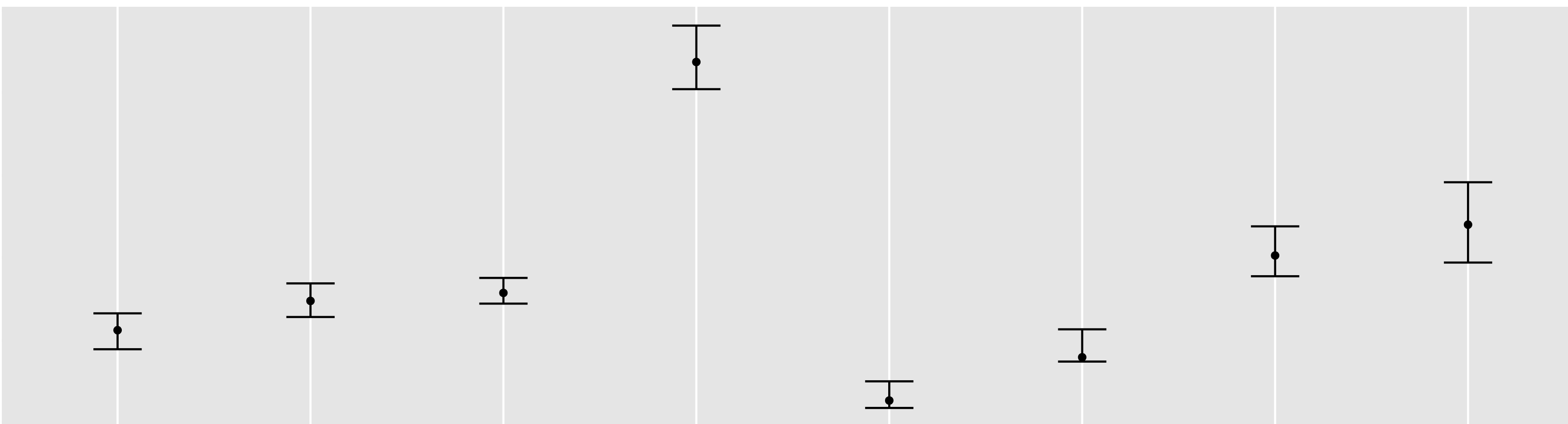




Predicted Adult Population Size by Generation



Degree-Day Accumulation



Final Population Size

Final Population Size

al

Dav

Riv

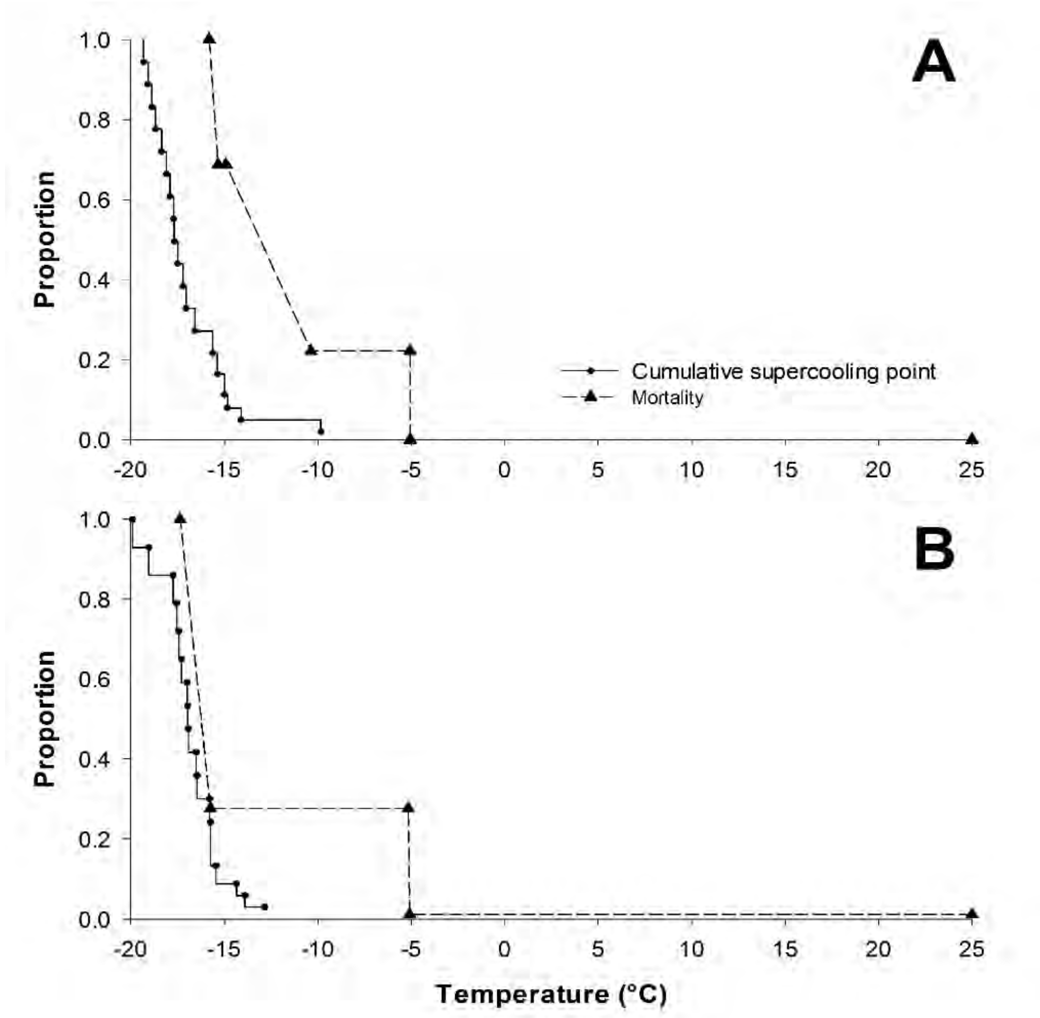
Nielsen et al. In review

Overwintering Mortality

- Haye et al. (2014) showed high survivorship once emerged from overwintering
- Polar Vortex killed 98% of BMSB in VA
  - >6,000 bugs held outside
- Cold tolerance was investigated in MN and VA

Cira – UMN
Kuhar - VT

Relationship between freezing and mortality: BMSB dies at higher temperatures than it freezes



-15°C (5°F) is lethal to BMSB

Cira, T. M., et al. Environ. Entomol. (in press)

- Subfreezing temps may greatly impact BMSB overwintering survival in natural sites
- However, many BMSB seek shelter inside of heated human dwellings

1.3.2 - Determine BMSB invasion patterns into new habitats

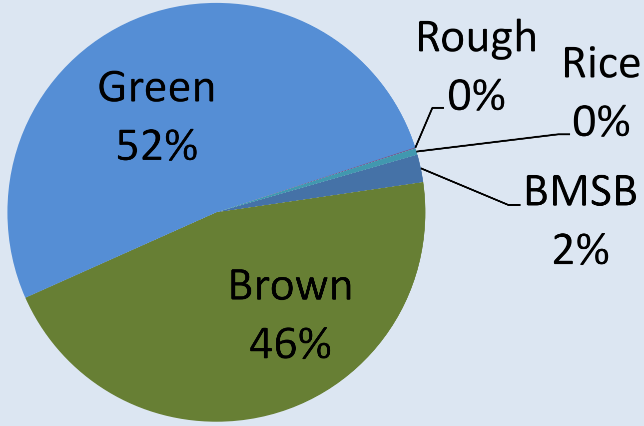
- Surveys of stink bug populations in NC and VA

1.4 - Identify landscape and temporal risk factors associated with BMSB on crops and in adjacent ecosystems

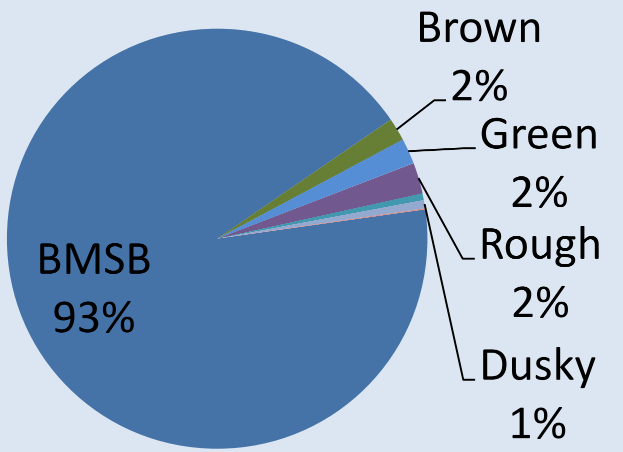
- Landscape features predicting populations in tomatoes

BMSB Surveys

- VA
  - In the Coastal Plain region, native green (52%) and brown (46%) stink bug counts were predominant, while counts of BMSB (2%) were minor.
  - In the Ridge and Valley (Blacksburg) area, BMSB accounted for 93% of all stink bugs observed.
- MD
  - the first and last appearance and abundance across time of BMSB along transects and found distinct preference for the highest elevations by BMSB

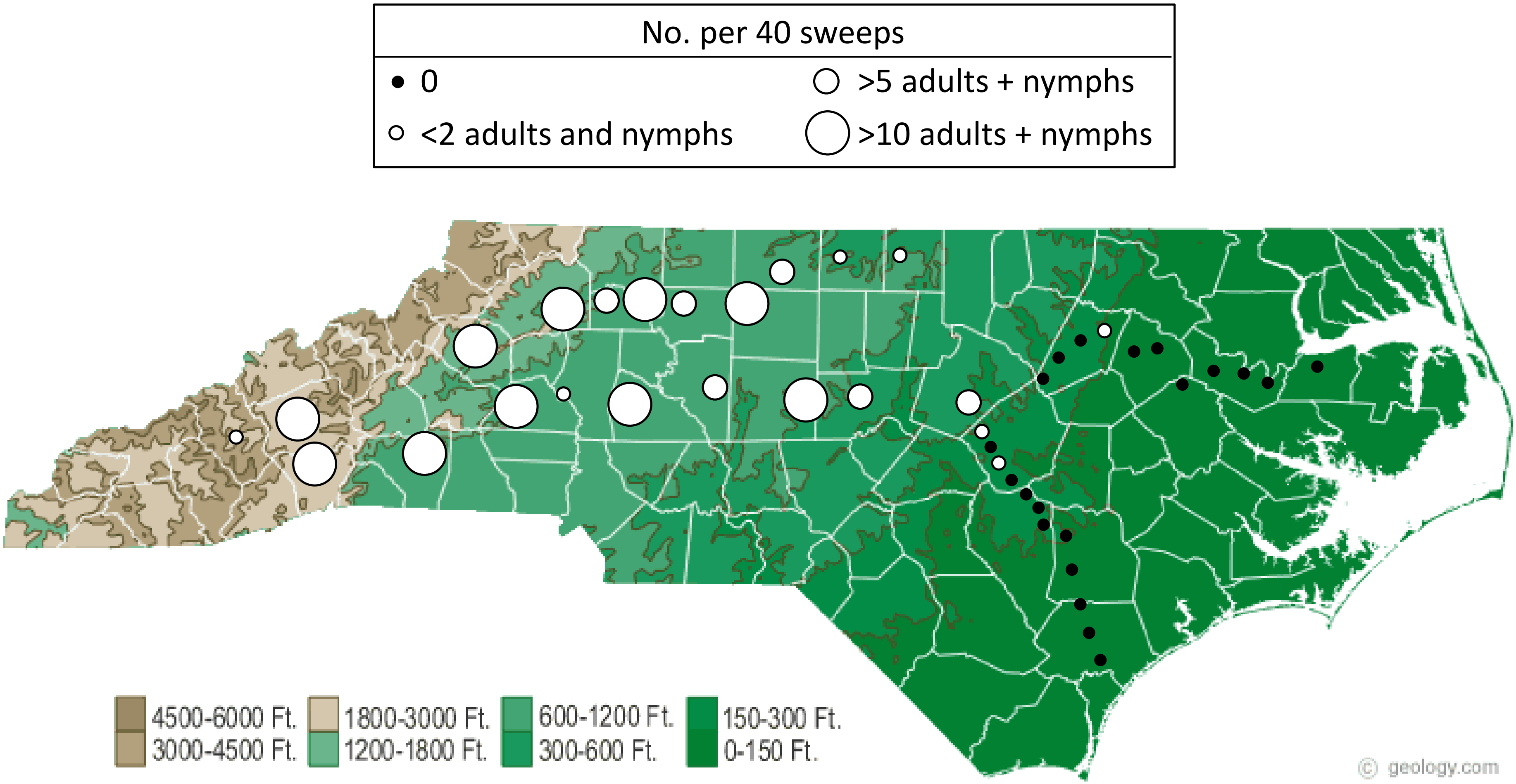


VA Coastal



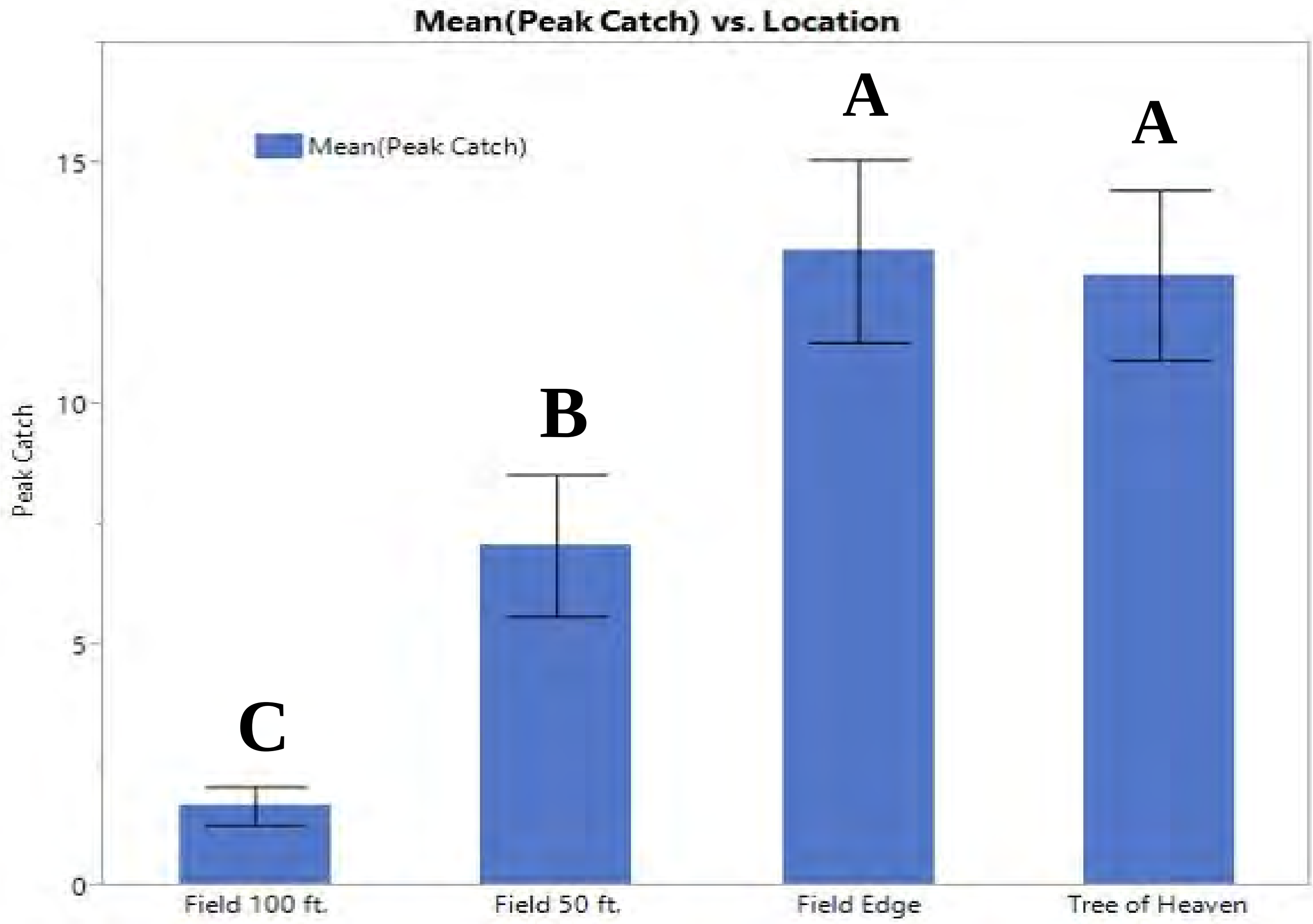
VA Ridge and Valley

BMSB in NC Soybeans – September 2014



Walgenbach - NCSU

Tree of Heaven Surveys

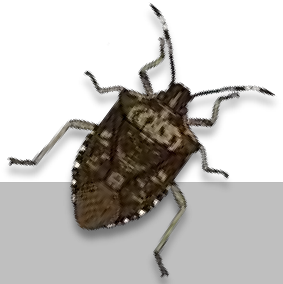

Mean(Peak Catch) vs. Location
Mean(Peak Catch)
Peak Catch
15
10
5
0
A
A
B
C
Field 100 ft.
Field 50 ft.
Field Edge
Tree of Heaven

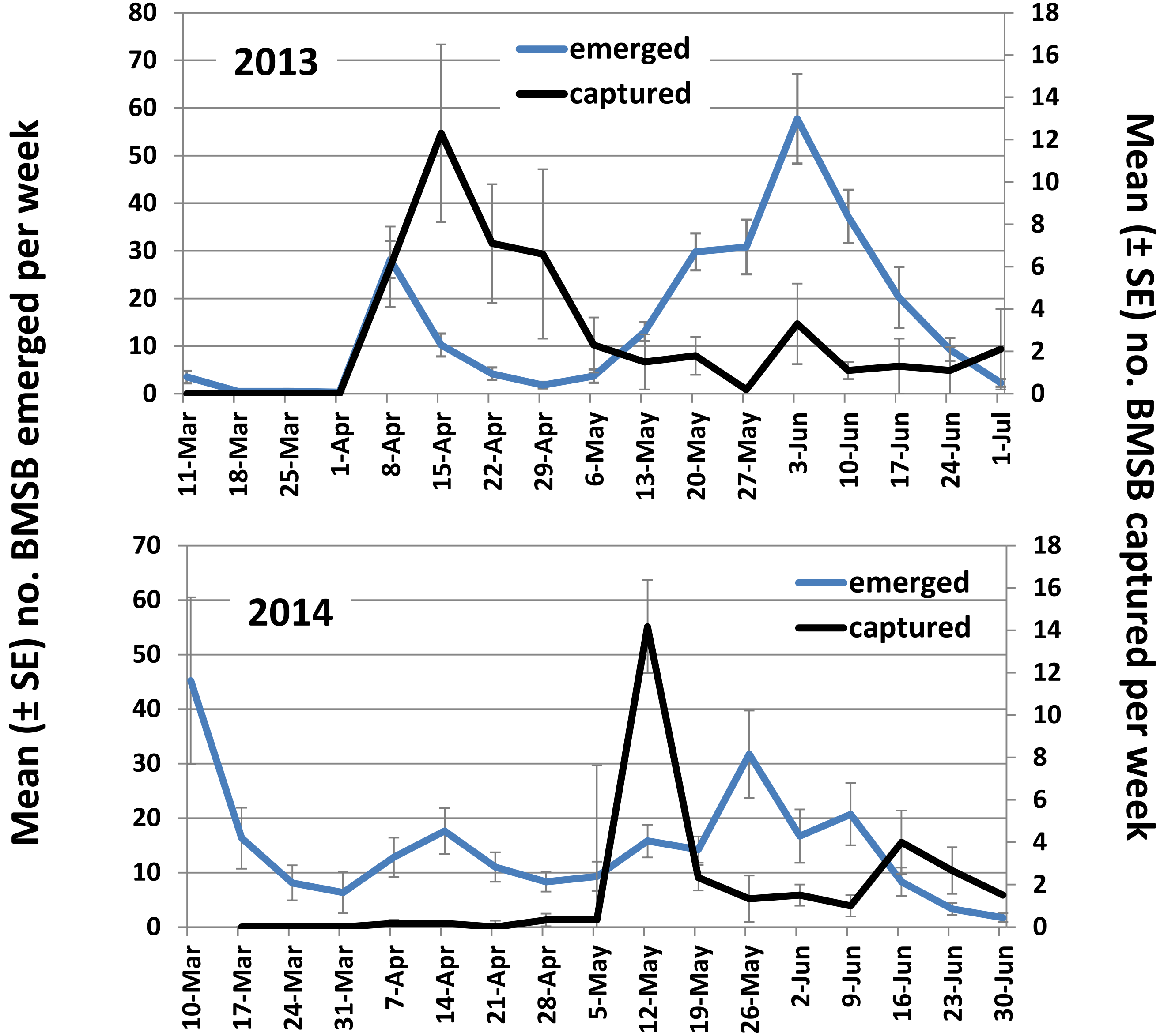
PA Landscape Analysis

- Arc GIS
  - NASS USDA
- 200m edge
- Landscape classes
  - Agriculture
  - Forest
  - Orchard
  - Other
- Forest edge and forest size were the significant landscape factors predicting BMSB damage

Phenology and Landscape Summary

- All estimates are going to yield slightly different estimates based on methods
- Generally, BMSB can be bivoltine across its US distribution
- **<u>13.4</u>**-14h daylength is the critical photoperiod
- Identification allows populations to be modeled
  - Model predicts high population growth in some areas (Asheville, NC and Davis, CA)
  - Model predicts low population growth in others (Wenatchee, WA)
- Populations are low in coastal areas and high inland and at high elevations
- Forest edge is associated with colonization of crops

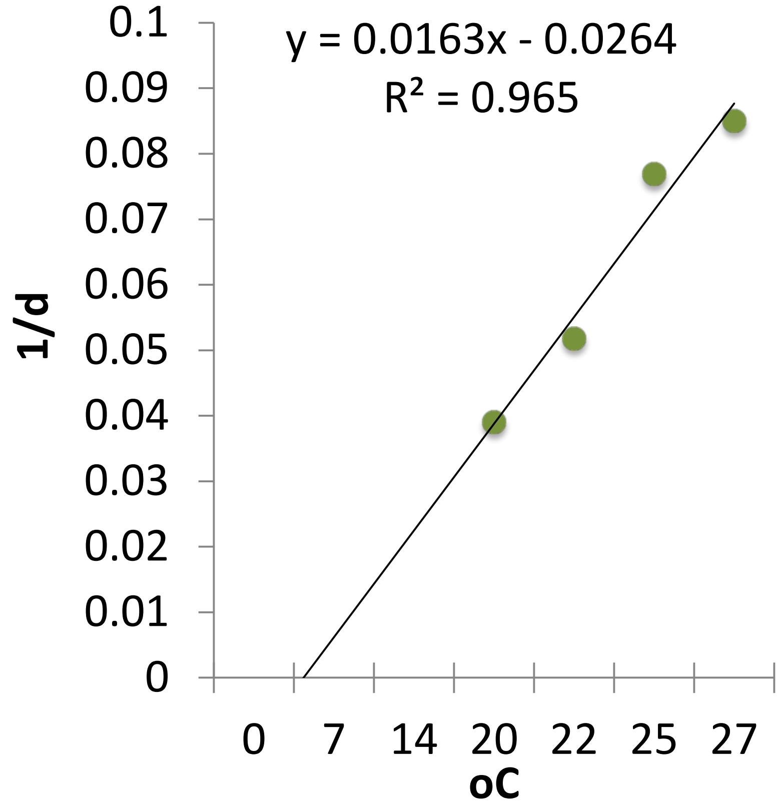




Mean (± SE) no. BMSB emerged per week
Mean (± SE) no. BMSB captured per week
2013
emerged
captured
80
70
60
50
40
30
20
10
0
18
16
14
12
10
8
6
4
2
0
11-Mar
18-Mar
25-Mar
1-Apr
8-Apr
15-Apr
22-Apr
29-Apr
6-May
13-May
20-May
27-May
3-Jun
10-Jun
17-Jun
24-Jun
1-Jul
2014
emerged
captured
70
60
50
40
30
20
10
0
18
16
14
12
10
8
6
4
2
0
10-Mar
17-Mar
24-Mar
31-Mar
7-Apr
14-Apr
21-Apr
28-Apr
5-May
12-May
19-May
26-May
2-Jun
9-Jun
16-Jun
23-Jun
30-Jun

Identification of BMSB Developmental Physiology

- Degree-day requirements for development identified
- DD requirements for oviposition still unclear
- Laboratory study



61 DD pre-oviposition period

1.1.2 - Movement to and from overwintering sites and overwintering survivorship

- When does BMSB emerge from overwintering sites?
- What is the duration of the emergence period?
- What factors influence emergence?
- Do captures in pheromone traps reflect emergence?
- Relevant to risk assessment, monitoring, intervention, and understanding BMSB population dynamics

Questions posed

- When does BMSB emerge from overwintering sites?
- What is the duration of the emergence period?
- What factors influence emergence?
- Do captures in pheromone traps reflect emergence?
- Relevant to risk assessment, monitoring, intervention, and understanding BMSB population dynamics

Conclusions

- Overwintering BMSB emerged over a period of ~2.5 months
- Early, smaller peak of emergence appeared to be primarily associated with a period of warmer temperatures (smaller and/or weak bugs depleted of resources?)
- Later, larger peak associated with temperature and/or change (stabilized?) in photoperiod
- Pheromone traps appeared to reflect onset emergence reasonably well
  - Marked bugs assumed to have dispersed from emergence site
- Need to conduct studies in north-south transect with naturally settling adults