

# Chemeketa CC – IPM Class

## Guest Lecture - Nov. 7, 2019

Len Coop

Assistant Professor (Practice)

Hort. Dept. and Integrated Plant Protection Center

“Phenology Modeling Basics for IPM”



**Oregon State**  
University

**I P P C**

integrated plant protection center



**Department of Horticulture**

# Topics for today's session:

- Introduction to phenology modeling (25 min)
- Introduction to running models at [USPEST.ORG](http://USPEST.ORG) (20 min)
- Class assignment: bronze birch borer modeling (40 min)

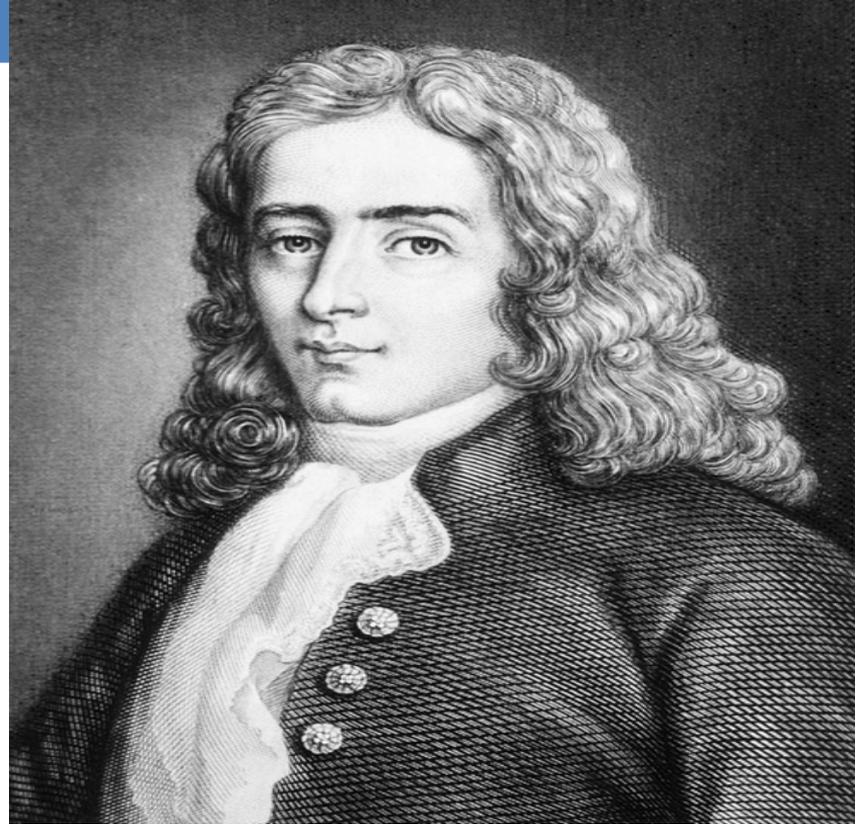
# ***Phenology and degree-day concepts***

- **Phenology**: the study of how organisms develop through stages over time
- Growth is a slightly broader concept: a plant growth model might predict **yield**, whereas a plant phenology model would simply predict **timing of plant stage development**
- **Degree-day**: a unit of heat whereby temperature is integrated over time, often referred to as “physiological time”

# René A. F. de Réaumur (1683-1757)

- Used daily mean temperatures to predict plant development in mid 18<sup>th</sup> Century
- The importance of threshold temperatures was recognized by mid-20<sup>th</sup> Century (i.e. Arnold, 1959)
- Threshold temperatures are low or high temperatures that limit development and growth

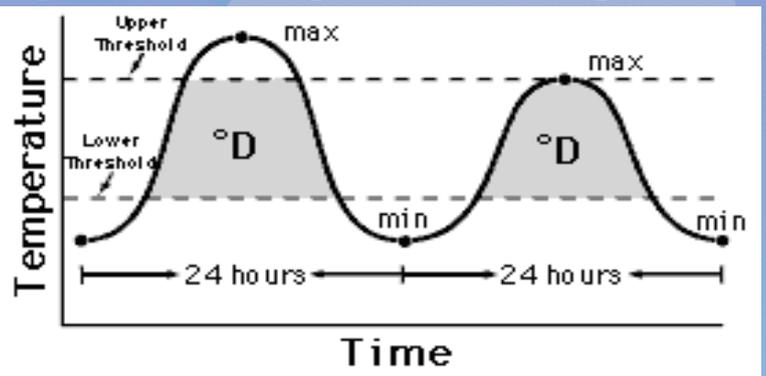
$$\frac{T_{max} + T_{min}}{2} - T_{base} = \text{degree days}$$



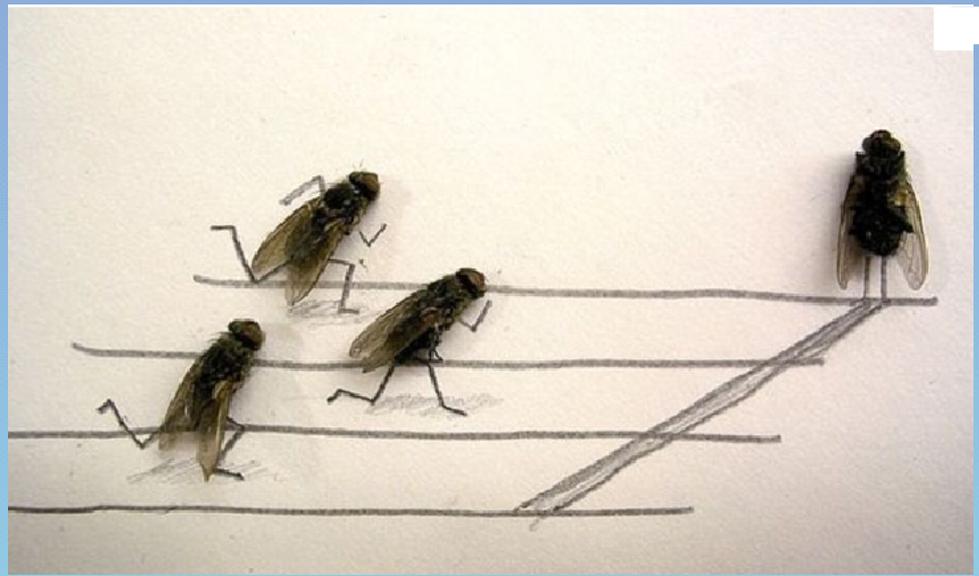
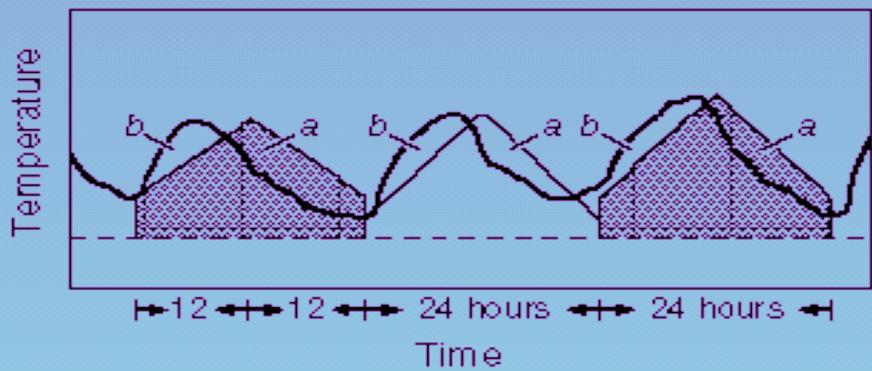
# ***Phenology and degree-day concepts***

- Cumulative degree-days: A heat unit method for recording physiological time used to represent development of many plants and animals that do not self regulate temperature
- Degree-day models in common use for timing of sampling and management events in agriculture; a cornerstone of IPM

# Degree-day calculations - method varies: Simple avg: $(\text{daily max} + \text{min})/2$ - low threshold

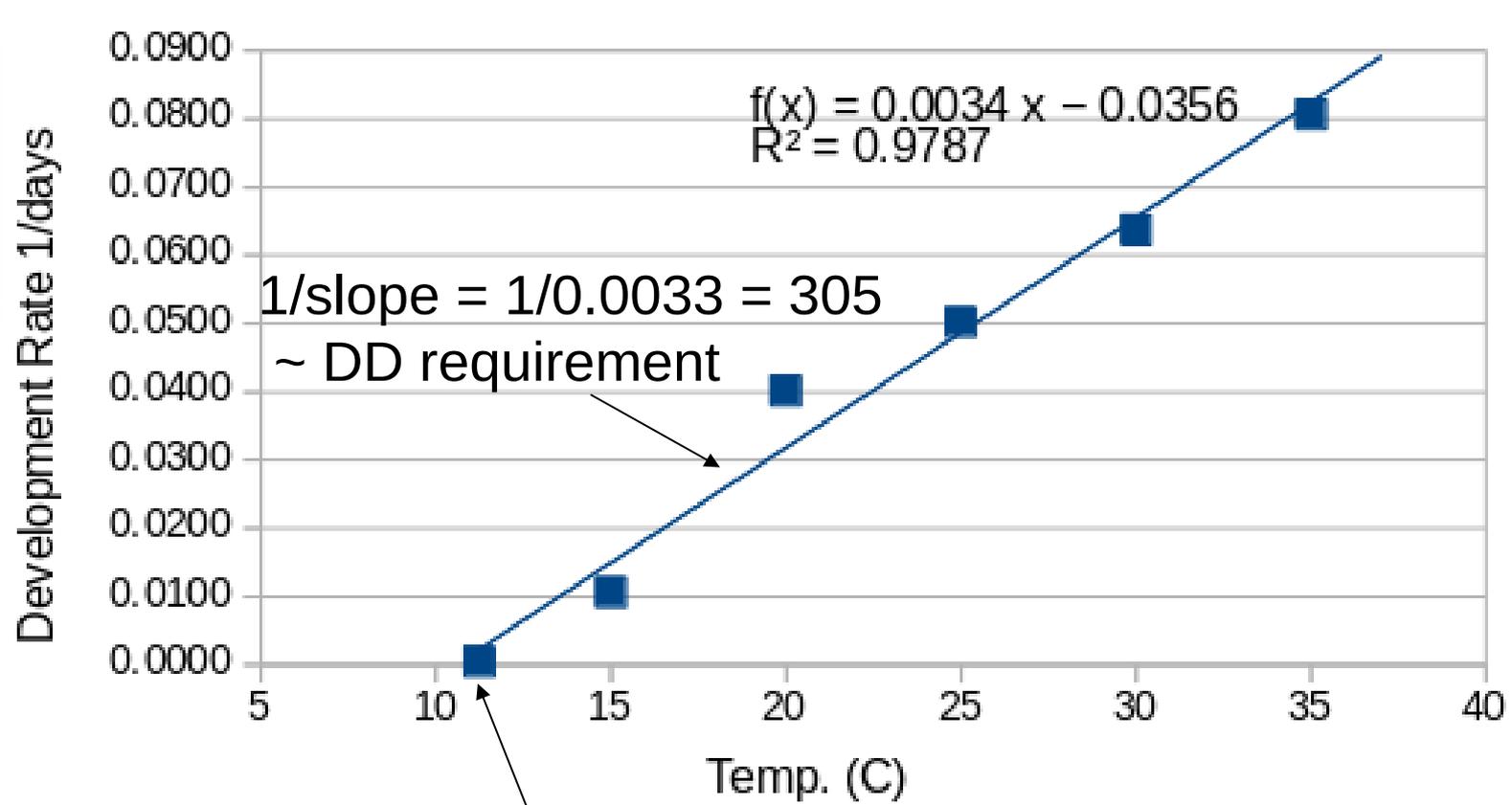


How fast are they going?



Single triangle compared with  
typical daily fluctuation

# Lab data: X-Intercept Method of finding thresholds (Campbell et al. 1974)



X-intercept =  $-a/b = 10.55 \text{ C} = T_{low}$

# Comparison of Degree-Day Calculation Methods

e. g. codling moth ( $T_{low}=50$ ,  $T_{upper}=88$ , method=s. sine, biofix to egg hatch=250 DDs)

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Method	Dds 4/20-5/26 2017
Single Sine	253
Double Sine	248
Single Triangle	237
Double Triangle	232
Simple Average	201
Corn GDD	299
Cooling DD	201

# Field Data: Lowest C.V. Method of Finding Tlow (Arnold 1959)

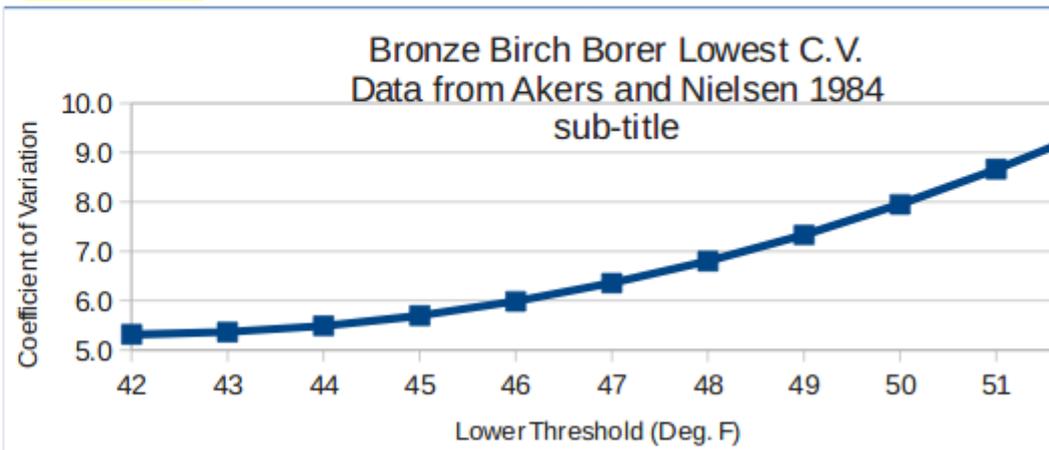
Table 2. Degree-days and C.V. for 10% adult emergence of bronze birch borer, using data from Tables 2 and 3 of Akers and Nielsen 1984; plus 1998 Woost

Estimated weather		10% actual										Tlow	
Station and Code	year	emerg. DOY	Month-Day	Deg. C. Deg. F.	5.56 42	6.11 43	6.67 44	7.22 45	7.78 46	8.33 47	8.89 48	9.44 49	
Columbus (COLUMOH)	1981	150	05-30-81	DDs (F):	1058.1	987.1	918.9	853.4	790.8	731.6	676	623.5	
	1982	143	05-23-82		980.6	922.9	867.9	815.4	765.3	717.3	671.5	627.8	
	1983	156	06-05-83		1088.7	1013.1	941.2	872.7	807.5	745.3	685.6	628.6	

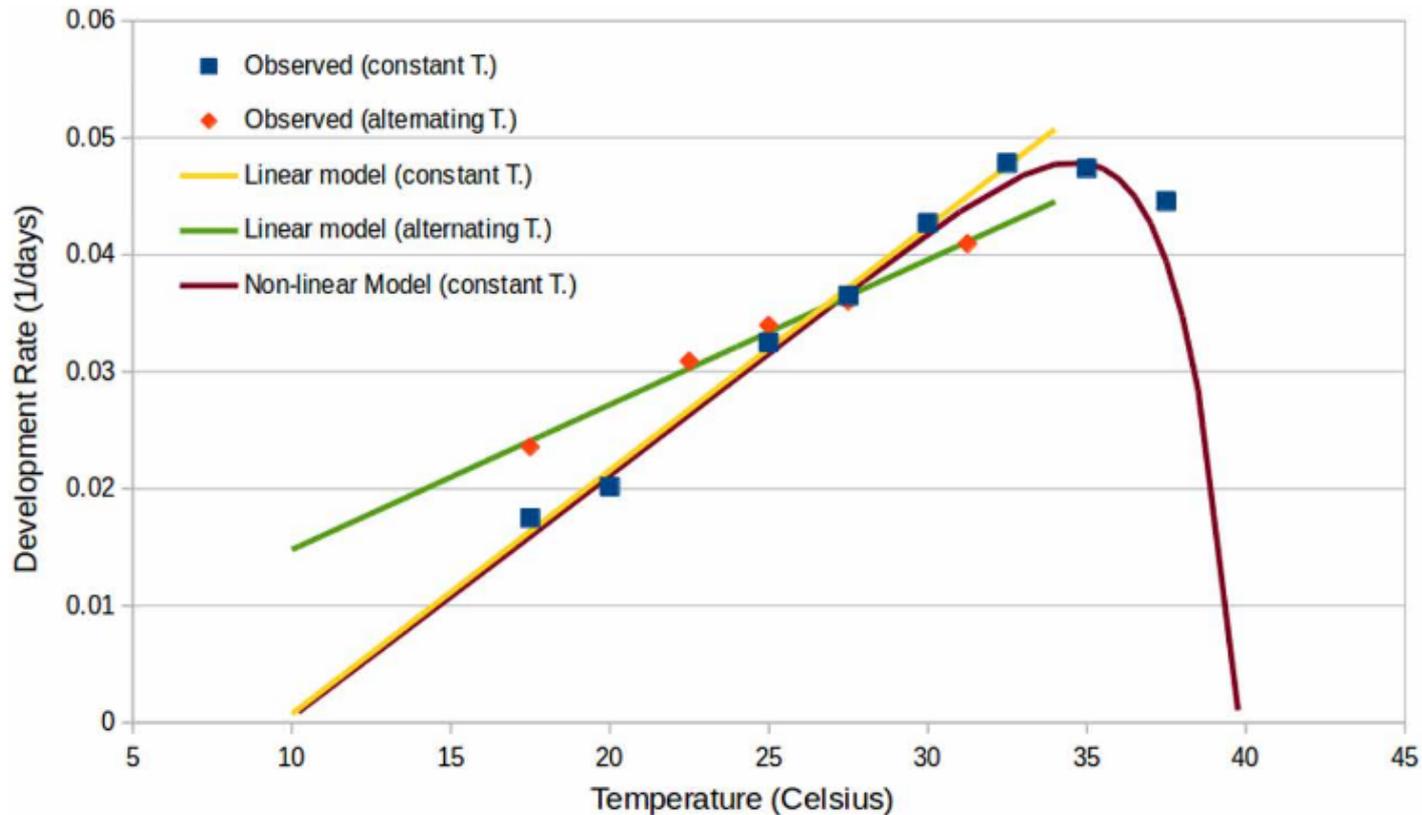
Results including all data:

avg	1024.8	956.3	890.9	828.5	769.0	712.3	658.5	607.4
sd	54.5	51.3	48.9	47.2	46.0	45.3	44.8	44.5
cv	5.3	5.4	5.5	5.7	6.0	6.4	6.8	7.3

Fig. 1. Lowest C.V. determination for 10% BBB emergence using data from Table 2 above.



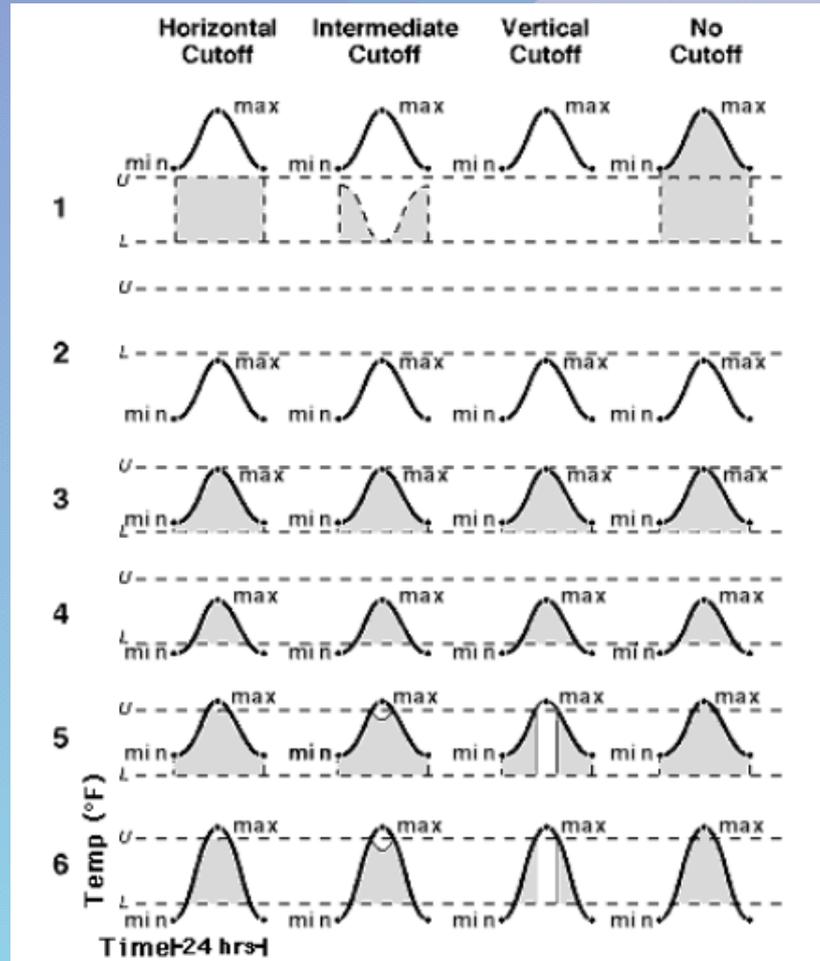
# Lab rearing at constant vs. alternating temperatures



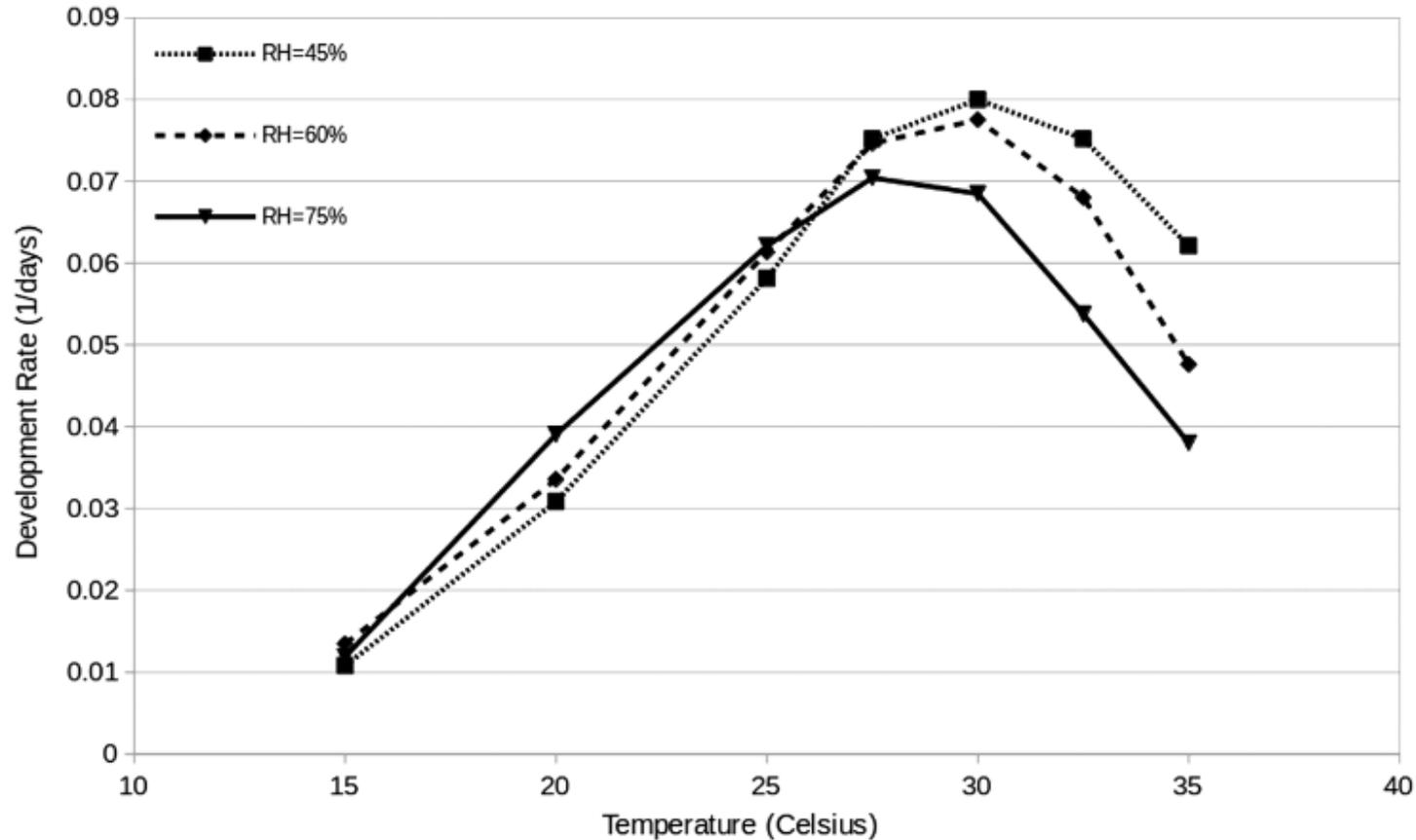
**Figure 6** Linear and non-linear development rate models for cotton bollworm, *Helicoverpa amigera*, fitted using data from a laboratory study of egg-to-adult development at constant and alternating temperatures. Source: adapted from Mironidis and Savopoulou-Soultani (2008).

# Comparison of Upper Cutoff Methods

1. Above both thresholds.
2. Below both thresholds.
3. Between both thresholds.
4. Intercepted by the lower threshold.
5. Intercepted by the upper threshold.
6. Intercepted by both thresholds.



# Lab rearing at constant temperatures and 3 humidity levels



**Figure 7** Plot depicting the effect of relative humidity (RH) on the temperature development rate curve for the scale insect *Phenacoccus solenopsis*. Source: data from Chen et al. (2015).

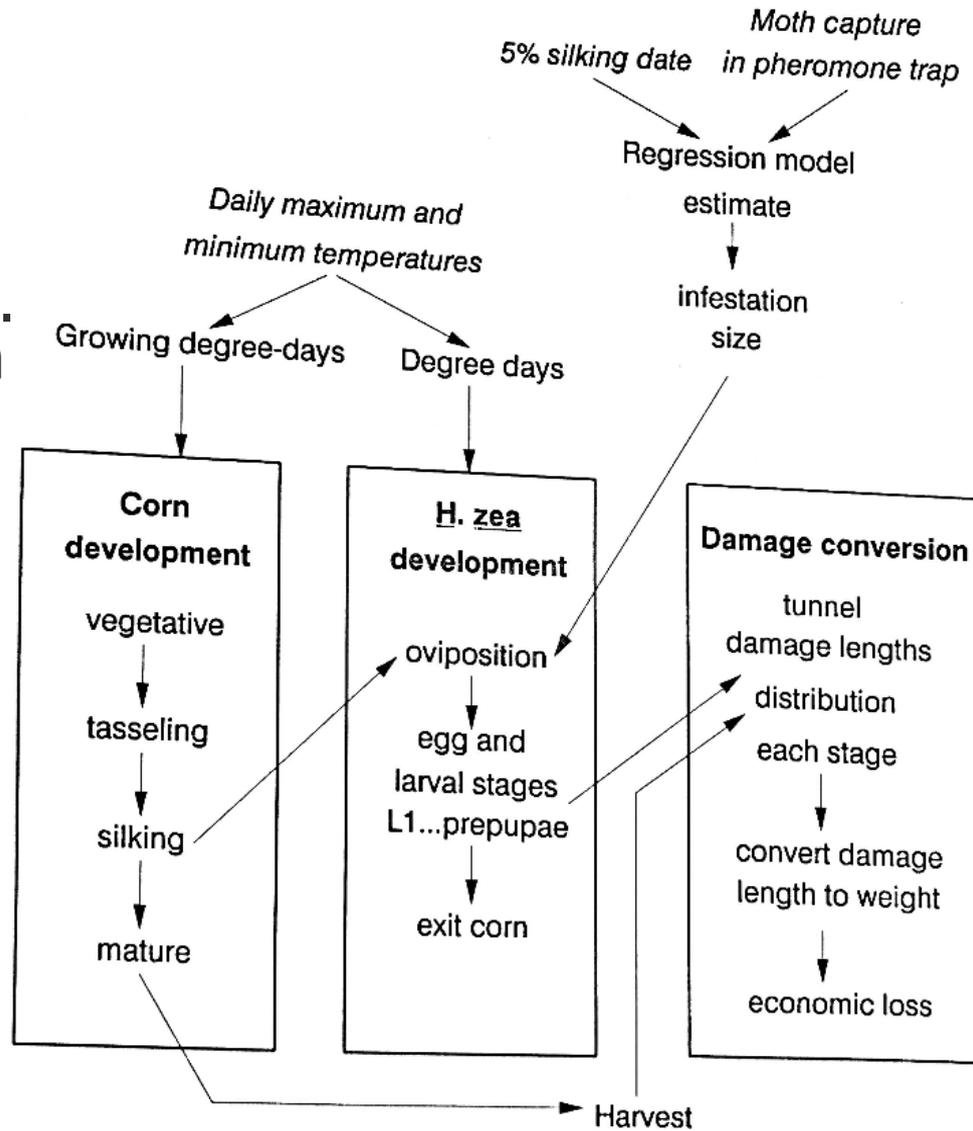
# CROPTIME - Thermal time to maturity

Cucumber 50/90F, SSHCO	Type	2 true leaves	Early flowering	First harvest	Accuracy (± days)
Cobra (DS)	Slicing	339	665	964	2.5
Marketmore-76 (DS)	Slicing	364	784	1211	1.1
Marketmore-76 (TP)	Slicing	-	344	805	1.9
Dasher II (DS)	Slicing	365	731	1060	1.8
Zapata (DS)	Pickling	380	688	984	2.7
Extreme (DS)	Pickling	366	692	946	1.2
Supremo (DS)	Pickling	366	677	981	0.8

~12 days diff.  
between  
varieties

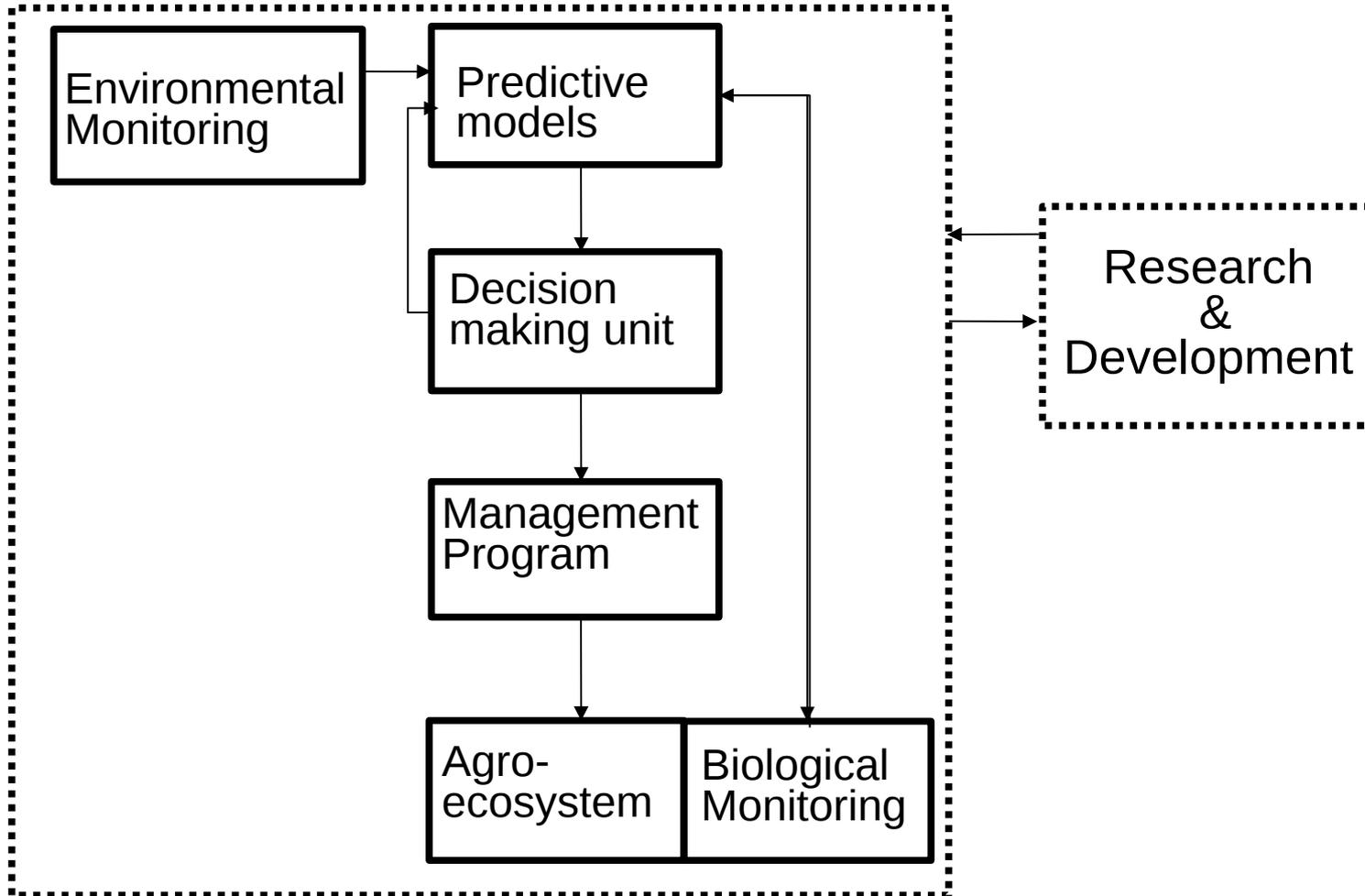
± 1-3 days  
accuracy

Systems modeling  
“Key Feature”:  
Conceptual Modeling: e.g. corn earworm development and damage to processed sweet corn



Using diagrams to conceptually describe a system with its subsystems or parts to consider the knowns and unknowns of each part

# Conceptual Model example: “Online IPM” (from Haynes et al. 1973 & Croft 1983)



# Integrated management of insect pests

Current and future developments

Emeritus Professor Marcos Kogan  
Oregon State University, USA

Professor Elvis 'Short' Heinrichs  
University of Nebraska-Lincoln, USA

## E-CHAPTER FROM THIS BOOK



## Advances in understanding species ecology: phenological and life cycle modeling of insect pests

Leonard Coop and Brittany S. Barker, Oregon State University, USA

- 1 Introduction
- 2 Concepts of the systems approach
- 3 Steps and phases of phenology model development
- 4 Phenology modeling data sources and approaches
- 5 Phenology modeling platforms and software
- 6 Life cycle systems model for *Drosophila suzukii*
- 7 Conclusion
- 8 Acknowledgements
- 9 References

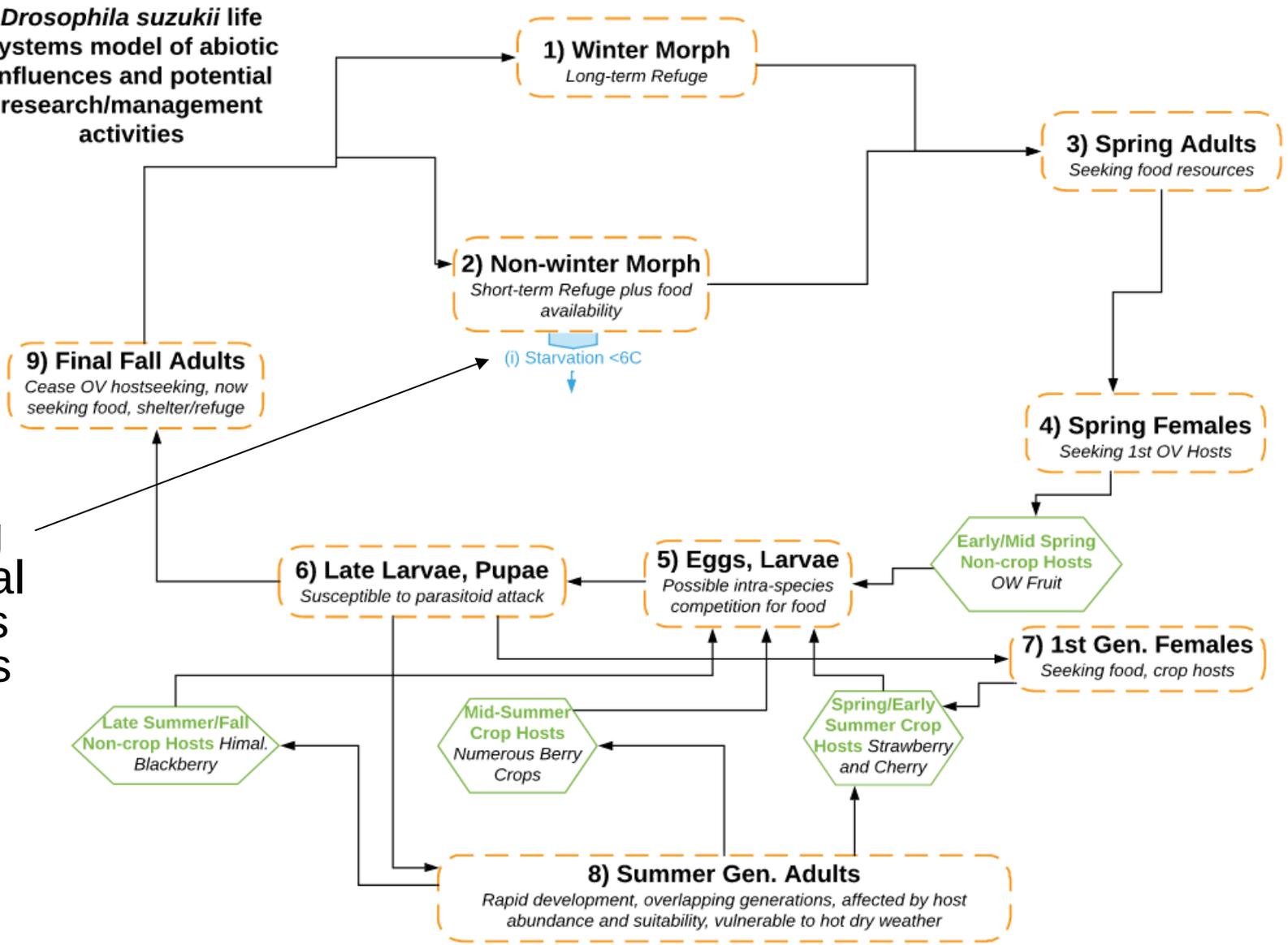
### 1 Introduction

Rapid and widespread invasions of crop insect pests have had devastating impacts on crop performance and production, and represent one of the important and urgent challenges to the world's food supply (Pimentel et al., 2001; Bradshaw et al., 2016; Paini et al., 2016). Successfully managing and preventing the establishment of insect pests requires data on their biology and ecology, including their life cycle stages and duration, environmental requirements for development and survival, and the timing of important life cycle events (i.e. phenology) such as first adult flight and egg hatching (Stohlgren and Schnase, 2006; Desneux et al., 2010; Cini et al., 2012). Applied models that combine this species-specific information with data on climate and weather can provide powerful predictions of the species' current and future distribution, population growth, and phenology (Strand, 2000; Stohlgren and Schnase, 2006; Donatelli et al., 2017; Orlandini et al., 2017). For this reason, predictive modeling tools are increasingly being integrated into decision support systems (DSSs) to help guide integrated pest management (IPM) efforts (Damos, 2015; Isard et al., 2015; F. et al., 2016; G. et al., 2017; C. et al., 2017).

*Drosophila suzukii* life systems model of abiotic influences and potential research/management activities

Step 1.  
Draw the organism's life cycle

Step 2a.  
Begin adding environmental stress factors or constraints if known

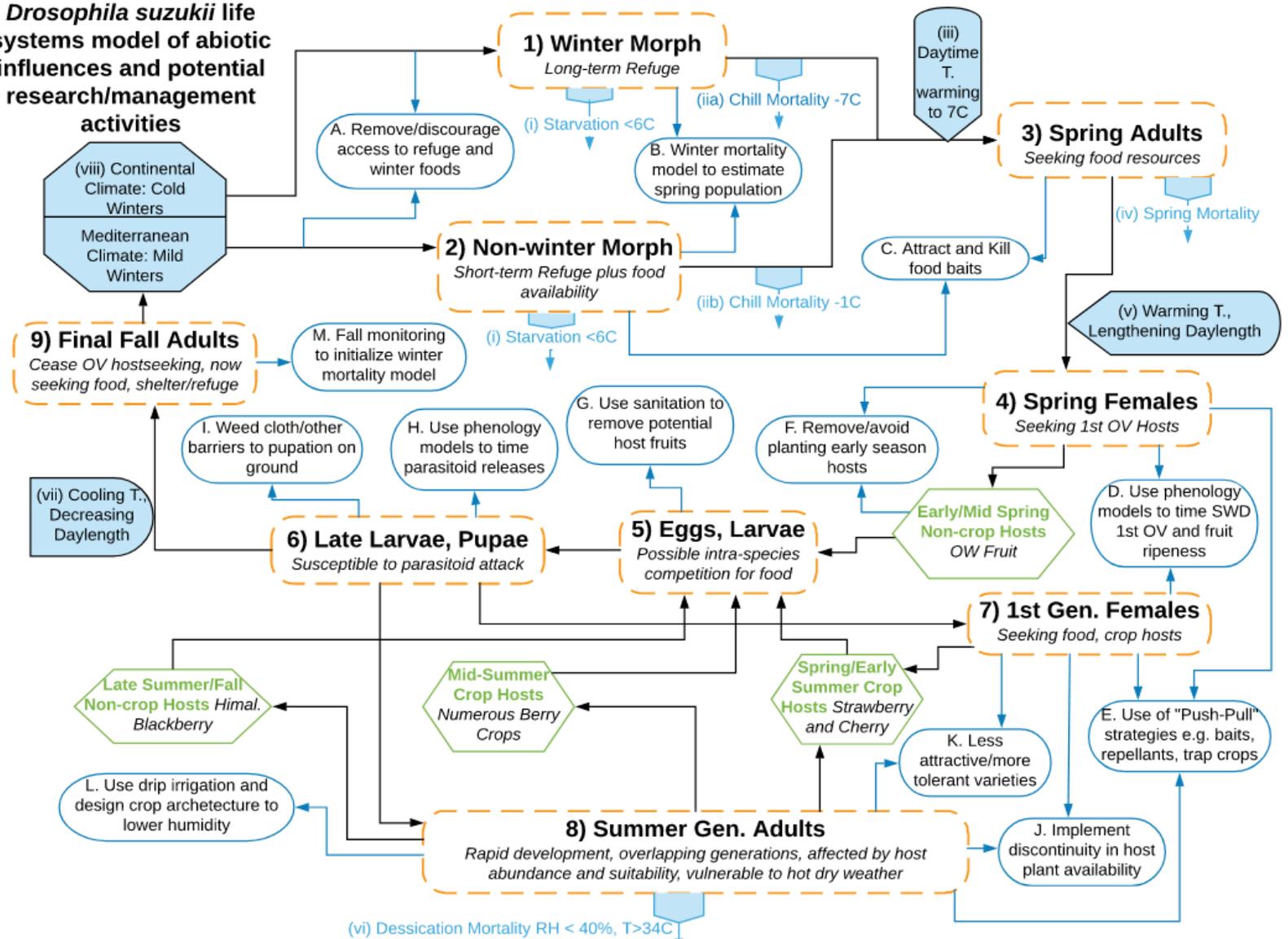




Step 3.  
Add  
management  
practices

Steps 4&5.  
Document  
and Refine

*Drosophila suzukii* life systems model of abiotic influences and potential research/management activities

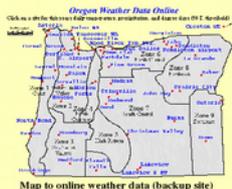


1997



ONLINE IPM WEATHER DATA - 1997

for pest management decision making in Oregon

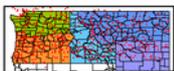


Contents

- Introduction and description of the data and its uses
- Backup Table of online and historical weather data
- Backup Map of online weather data
- Java Degree-Day Calculator linked to the weather data

2004

IPM Weather Data and Degree-Days



for agricultural and pest management decision making in the West

Basics	DD Maps	Degree-day Calculators	Degree-day Models
<p><b>What's new</b> Brief user survey instructions with data description</p> <p><b>Frequently asked questions (FAQ)</b></p> <p>6/02 Report 4/03 Poster 11/01 Decision Tools and DD mapping - slideshows</p> <p><b>Related web sites</b></p>	<p>Base 41 (or 45 in MT) and 50 DD Maps for ID, MT, OR, WA, WY, and 11 western states updated daily</p> <p>Oregon Base 41 and 50 DD maps updated daily</p> <p>Oregon Base 32 and 52 DD maps updated daily</p> <p>Full station list</p>	<p>Calculator linked from 1300+ weather stations via table: 110 Oregon, 176 Oregon RAW/S/Std, 12 Medford, 8 Hood River OR (grower networks), 201 Washington, 235 Idaho, 294 Montana, 141 Wyoming, 241 SW USA, 30 Alaska, and 51 BC, AB &amp; SK Canada locations</p> <p>Weather station maps linked to calculator (select nearest weather station from a map) Mapsize: 680 pixels Region: W US</p> <p>DD Models Map Shortcut: (select nearest weather station from a map) coding moth [apple &amp; pear] Brunner and Hoyt (1987) Mapsize: 680 pixels Region: W US</p> <p>Plant disease models: Fire Blight, Apple scab, Pear scab and Grass seed stem rot; Crop models: Wheat plus 15 more</p>	<p>Online phenology models and degree-day calculator: 48 models, file uploads, forecasts, photos, celcius, ending date, bookmark most settings, photos - updated May 19, 2004</p> <p>Insect models: Coding moth, OBLR, Cherry Fruit Fly, and Filbertworm plus 19 more</p> <p>Plant disease models: Fire Blight, Apple scab, Pear scab and Grass seed stem rot; Crop models: Wheat plus 15 more</p>

2001

IPM Weather Data and Degree-Days for agricultural and pest management decision making in the Northwest

Basics	Read Only Data	Degree-day Calculators	Degree-day Models
<p><b>What's new</b> Introduction with data description</p> <p><b>Frequently asked questions (FAQ)</b></p> <p>Mar. 2001 Report Nov. 2001 Decision Tools - slide presentation</p> <p><b>Related web sites</b></p>	<p>Map access to many Oregon 2001, 2000, 1999, 1998 and 1997 weather data files and to full station list</p> <p>Base 41 and 50 degree-day maps updated daily Medford</p> <p>Base 32 and 52 degree-day maps updated daily NW Oregon/Hermiston (Downy Brome DDs) and Ontario/SW ID (Lygus DDs)</p>	<p>Weather station tables linked to calculator: 108 Oregon, 105 Oregon RAW/S, 10 Medford, 7 Hood River OR (grower networks), 86 Washington, 96 Idaho, 94 Montana, 54 Wyoming, 31 Alaska, and 43 BC &amp; AB Canada locations</p> <p>Weather station maps linked to calculator (select nearest weather station from a map) Mapsize: 680 pixels Region: NW</p> <p>Degree-day calculator Link to same product as models but with no species selected - enter your own thresholds</p> <p>Degree-day mapping calculator: design your own DD maps using a wide range of options - revised Mar 28, 2001</p>	<p>Online phenology models and degree-day calculator: 5-in-1 features - file uploads, forecasts, photos, celcius, ending date, bookmark most settings, photos, and more - updated Feb 25, 2001</p> <p>Popular insect models include: Coding moth, OBLR, Cherry Fruit Fly, and Filbertworm (plus 19 more)</p> <p>Plant disease models include: Fire Blight, Apple scab, and Pear scab</p> <p>Crop models include: Wheat and Jubilee sweet corn plus 14 more</p>

2007

See the what's new page, and please fill out our brief user survey.

IPM Weather Data and Degree-Days for agricultural and pest management decision making in the US

Basics	DD Maps	Degree-day Calculators	Degree-day Models
<p><b>What's new</b> Brief user survey this site is free - please provide us feedback and thank!</p> <p><b>Degree-day usage instructions, data description</b></p> <p><b>Frequently asked questions (FAQ)</b></p> <p>6/02 Report 4/03 Poster 11/01 Decision Tools and DD mapping - slideshows</p> <p><b>Related web sites</b></p>	<p>Base 41 (or 45 in MT) and 50 DD Maps for 9 MT OR WA WY and 11 western states updated daily</p> <p>Oregon Base 41 and 50 DD maps updated daily</p> <p>Oregon Base 32 and 52 DD maps updated daily</p> <p>Full station list</p>	<p>Calculator linked from 10,400+ weather stations via tables: 667 Oregon, 12 Medford, 30 Hood River, 16 Milson-Freewater OR (grower networks), 424 WA, 329 ID, 388 MT, 234 WY, 958 HI Central, 552 Central Labels Central, 1065 NE, 2767 SW, 899 S Central, 1230 SC, 220 Alaska, and 189 S Canada locations</p> <p>Weather station maps linked to calculator (select nearest weather station from a map) Mapsize: 680 pixels Region: S-state NW</p> <p>DD Models Map Shortcut: (select nearest weather station from a map) coding moth [apple &amp; pear] Brunner and Hoyt (1987) Mapsize: 680 pixels Region: S-state NW</p> <p>US Degree-day mapping calculator: new version for 48 US states - Apr 13, 2005</p>	<p>Online phenology models and degree-day calculator: 52 models, file uploads, forecasts, celcius, bookmark most settings - updated May 19, 2004</p> <p>Insect models: Coding moth, OBLR, Cherry Fruit Fly, and Filbertworm plus 26 more</p> <p>Plant disease models: Fire Blight, Apple scab, Pear scab and Grass seed stem rot; Crop models: Wheat plus 15 more</p>

History of USPEST.ORG home page

2010 - 2019

MyPest Page - IPM Pest and Plant Disease Models and Forecasting



for Agricultural, Pest Management, and Plant Biosecurity Decision Support in the US

- Introduction
- Quick Start
- Map Index
- Shortcut Links
- Degree-day Maps

Introduction:

This website combines US weather and climate data (29,000+ locations) with plant pest and disease models to support a wide range of agricultural decision making needs. We currently serve over 120 degree-day and 23 hourly weather models for integrated pest management (IPM), invasive species, biological control, and other uses for the full USA. A more complete project description here.

Our primary Degree-Day (DD) Model & Calculator Interfaces (see Shortcut Links tab for others):

1. "ddmodel.us" Google map DD model interface (standard version)
2. "MyPest Page" Disease risk, DD, other models (also see Quick Start tab)

Additional Resources:

1. What's new
2. Online tutorials
3. Degree-day usage instructions
4. How-to make webpage bookmarks (technical document #1)
5. How-to make "mashups" with uspest.org charts and tables (tech. doc. #2)
6. Frequently asked questions
7. Related web sites
8. 2018 past usage/no. DD model runs

Presentations:

1. Pest Event Mapping: A New Tool for Prediction of Insect Phenology (paper .pdf) (slides .pdf)
2. Crops and Climate - Has it been getting warmer in the Pacific NW & how will that affect plant/crop phenology? Small Farms Conference, Corvallis OR Feb 28, 2015 (slides .pdf)
3. Medium- and Extended-Range Weather and Climate Forecasts Scaled and Tested for IPM Decision Support in US States NW Climate Conf., Skamania, WA Nov. 2016 (poster .pdf)
4. Systems modeling of crop and insect development for agricultural decision support OSU Horticulture Seminar, Corvallis, OR Nov. 2017 (60 min. video)
5. Weather and Climate Driven Models for IPM and Invasive Species Management 9th International IPM Symposium, Mar. 2018 (poster .pdf)
6. DDRP: Modeling Degree-Days, Risk of Establishment, and Phenological Event Maps Pacific Branch Entomological Society Annual Meeting, Apr. 2019 (poster .pdf)

Partners and Support:

We are actively collaborating and partnering with Fox Weather, LLC and the National Weather Service for forecasts, with the OSU PRISM Climate group for climate data, with the W. Region IPM Center as a Signature Program, and with numerous state and private IPM decision support programs and entities. Funding has been provided by numerous USDA NIFA grants, USDA PPQ, RMA and ipmPIPE grants, NPDN grants, WR-IPM Center and Oregon Statewide IPM funds, and local and regional commodity groups.



# USPEST.ORG

## Mypest page

- 150 models

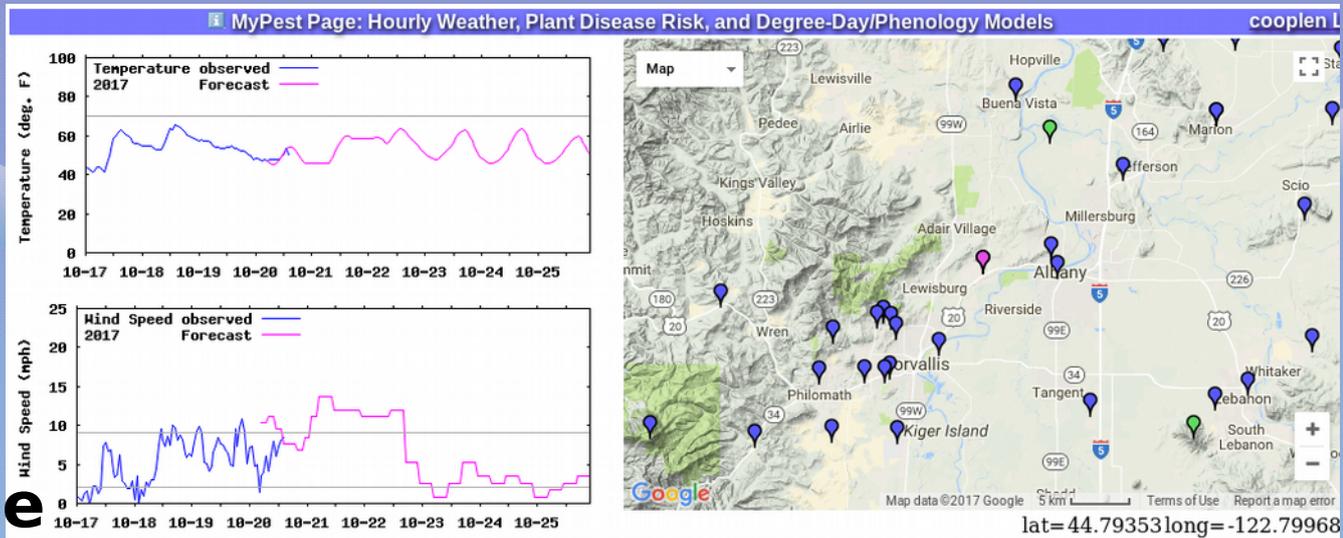
128 phenology/  
degree-day

22 hourly driven

e.g. plant disease

Infection risk

- 29,000 weather  
stations



CRVO AGRIMET 44.6342 -123.1897  
2017 CORVALLIS OR elevation: 230'

My Virtual Stations

Refresh - click to reset display

- Display Dates
- Weather Parameters
- Plant Disease/Other Hourly Driven Models
- Blueberry Mummy Berry Ascospore Infection Risk
- Degree-day/Phenology Models
- Codling Moth

- Display Settings
  - Disable Forecast Data Display
  - Use NWS Digital Forecast
  - Leaf Wetness if Relative Humidity (%) above
  - Ignore Leaf Wetness Sensor Data (if available)
  - Ignore Sensor Data & Precip in Leaf Wetness Calculation
  - Plot QA for Temperature and Dew Point
- Replace with virtual data:
- Custom Threshold Lines for Weather Graphs

**USPEST.ORG**  
**Mobile & Web App**  
**uspest.org/dd/model\_app**  
**- 128 phenology/  
degree-day**  
**- 29,000 weather  
stations**

## Online Phenology and Degree-day Models for agricultural and pest management decision making in the US

[Intro](#)[Station](#)[Model](#)[Output](#)[Graph](#)

bronze birch borer at KSLE, Salem: McNary Field OR, 2019

### Species / Model

Select a model or species. (see list of models) To choose your own calculation method and threshold temperatures, chose "degree-day calculator".

**i** Model category

Model

### Dates

Model is designed to start on fixed date: Jan 1

Start:

End:

### Options

**i** Forecast type: after 7 days, use

Celsius:



bronze birch borer [birch trees]  
native insect model of OSU IPPC model analysis

# In beta testing: register for email “push notifications” for hop powdery mildew – w/Dan U. & Dave Gent, USDA ARS

## USPEST.ORG Plant Disease Risk Model Email Notification Account Management: Settings

Currently supported model: Hop Powdery Mildew Risk Index.

**This software has not yet been thoroughly tested. Please report any problems you encounter to the developer at [upper@peak.org](mailto:upper@peak.org).**

You are logged in as `coopl@bcc.orst.edu`. You can change your settings (and your password) here.

### + Change Password

### - Stations

You can monitor up to three stations.

#### Station 1

  Enable

#### Station 2

  Enable

#### Station 3

  Enable

### - Hop Powdery Mildew

In which months do you want hop powdery mildew emails?

- January
- February
- March
- April
- May
- June
- July
- August
- September
- October
- November
- December

During those months, which days of the week do you want hop powdery mildew emails?

- Sunday
- Monday
- Tuesday
- Wednesday
- Thursday
- Friday
- Saturday

Time span (days) (Note that the last 5-6 days will be forecast.)  7  14  30

Preferred format:

From [no-reply@uspest.org](mailto:no-reply@uspest.org)  
 Subject **Pest Risk Index Report**  
 To Len Coop

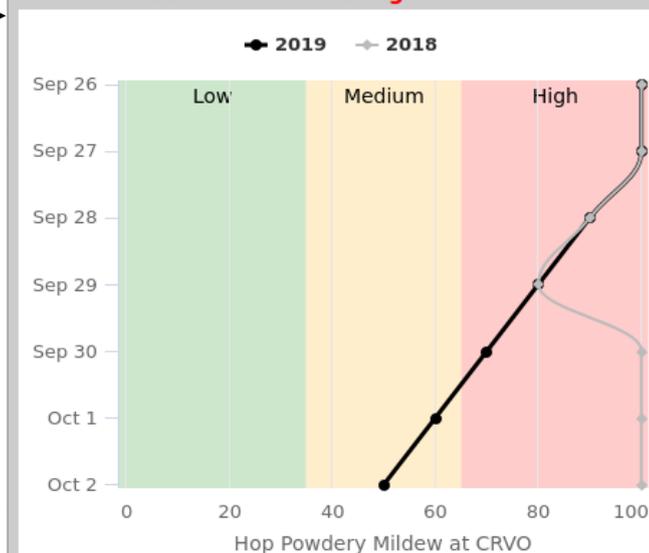
Pest risk index report for Friday, September 27, 2019 :

### Hop Powdery Mildew (susceptible varieties)

#### Hops Powdery Mildew Risk for Station CRVO

[latest index online](#)

Date	2019		2018	
	Risk index	Risk class	Risk index	Risk class
Sep 26	100	High	100	High
<b>Sep 27</b>	100	High	100	High
Sep 28	90	High	90	High
Sep 29	80	High	80	High
Sep 30	70	High	100	High
Oct 1	60	Medium	100	High
Oct 2	50	Medium	100	High



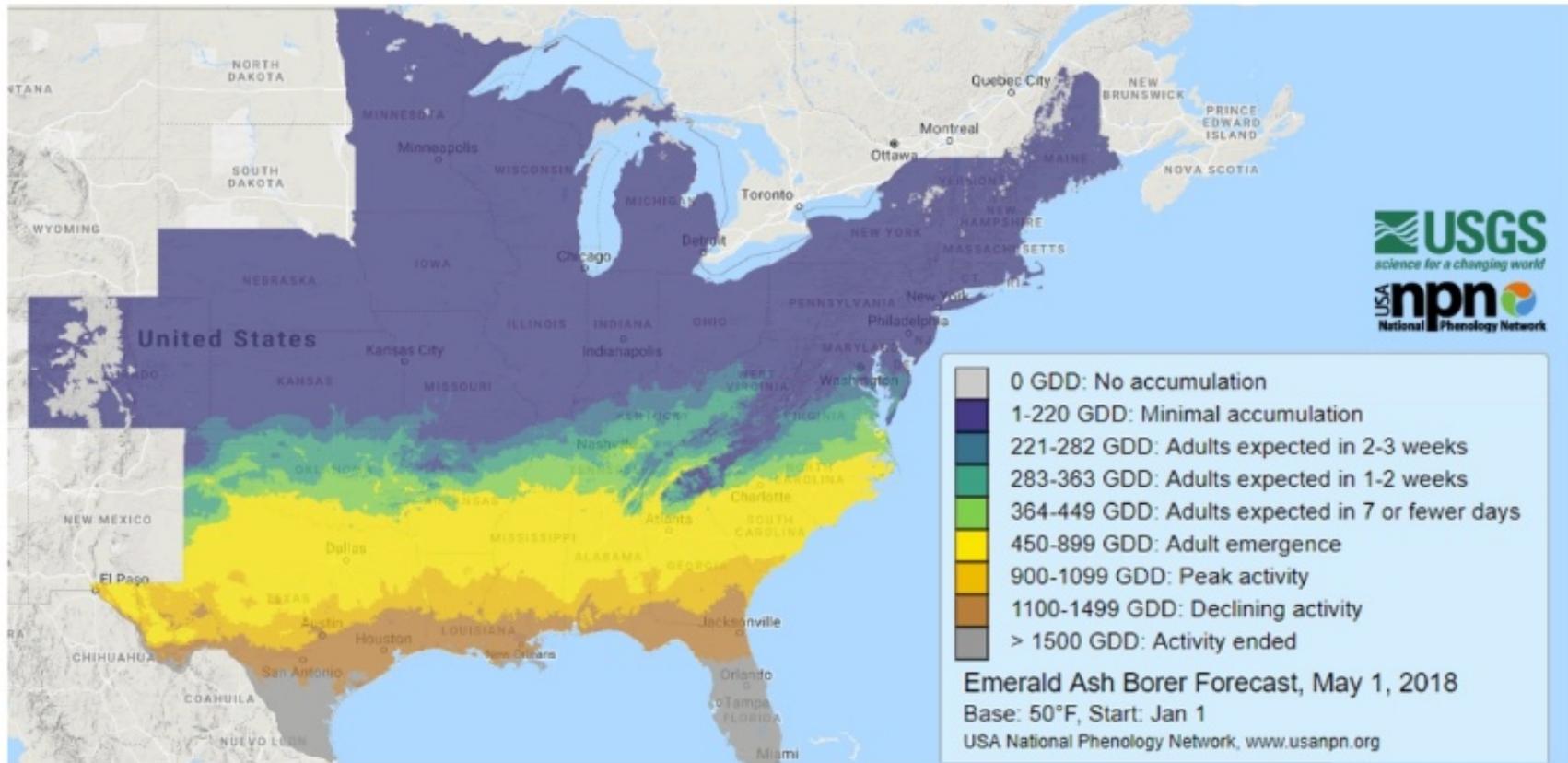
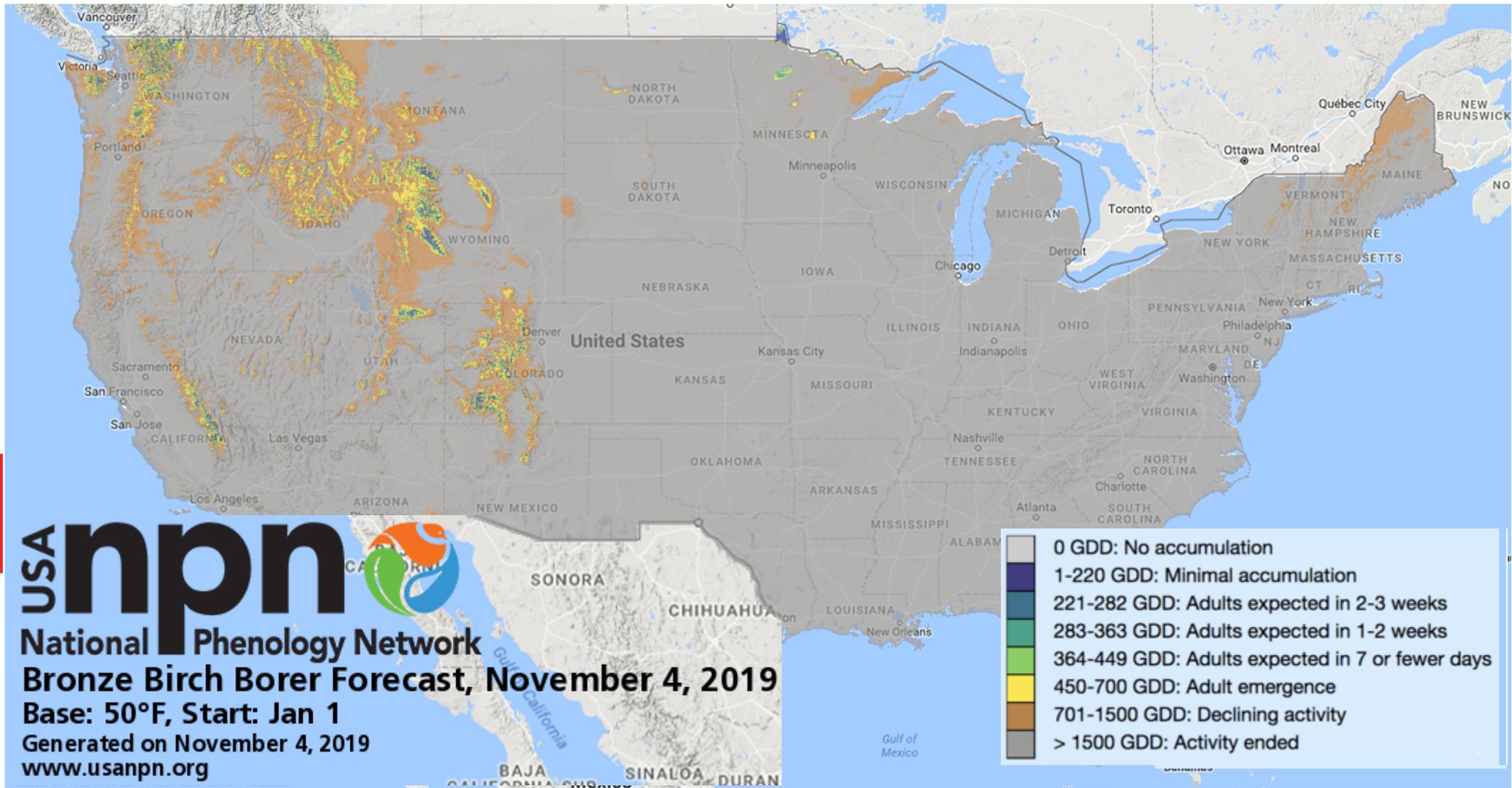


Figure 1. Pheno Forecast map for emerald ash borer for May 1, 2018. Colors indicate the status of adult emergence. The status of a location is determined by comparing the local GDD accumulation to a published heat accumulation threshold for the life cycle stage.



# Class exercise: use DD model/calculator to compare two models

## Bronze Birch Borer Model Parameters:

**Lower threshold: 43 degrees F (6.1 degrees C)**

**Upper threshold: 100 degrees F (37.8 degrees C) (nominal - none determined)**

**Start Date: Jan. 1st**

**Calculation Method: single sine**

**Model based on several sources, primarily Akers and Nielsen (1984), Muilenburg and Herms (1984)**

**Region of known use: Data and observations used for model development from Ohio, Michigan, and Pennsylvania**

**Validation status: A few observations from 5 states are in accordance with model predictions.**

**on multiple years data from those states, some of which are approximate average date-based**

**Table 1: Events and degree-days used in bronze birch borer (BBB) model:**

Event	DDs (F)	DDs (C)
Prepupal larvae in overwintering cells in bark	250	139
Beginning of pupation	400	222
End of pupation	700	389
First adults exit trees	750	417
10% adult emergence	950	528
50% adult emergence	1100	611
Beginning of egg hatch and larval tunneling	1400	778
90% adult emergence	1600	889
Adult activity and egg hatch ended, larvae continue tunneling	2050	1139

**USA npn**  
National Phenology Network

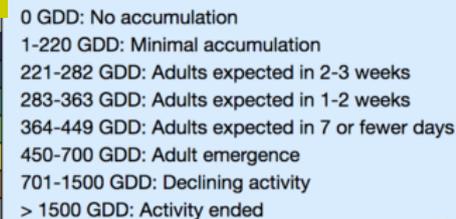
**Bronze Birch Borer Forecast, November 4, 2019**

**Base: 50°F, Start: Jan 1**

Generated on November 4, 2019

[www.usanpn.org](http://www.usanpn.org)

Major funding provided by



# Chemeketa CC – Intro to Phenology Models

Questions? Ready for Exercises?

Len Coop

Assistant Professor (Practice)

Hort. Dept. and Integrated Plant Protection Center