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

IPPC
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 (20 min)
- Class assignment: bronze birch borer modeling (40 min)

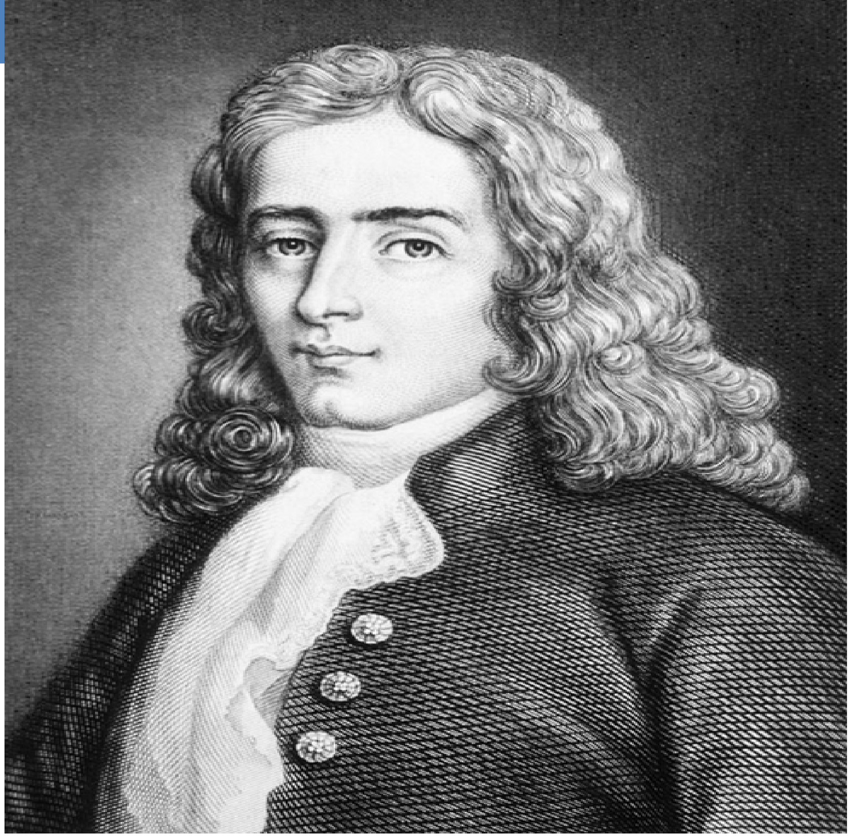
Phenology and degree-day concepts

- 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 18th Century
- The importance of threshold temperatures was recognized by mid-20th Century (i.e. Arnold, 1959)
- Threshold temperatures are low or high temperatures that limit development and growth

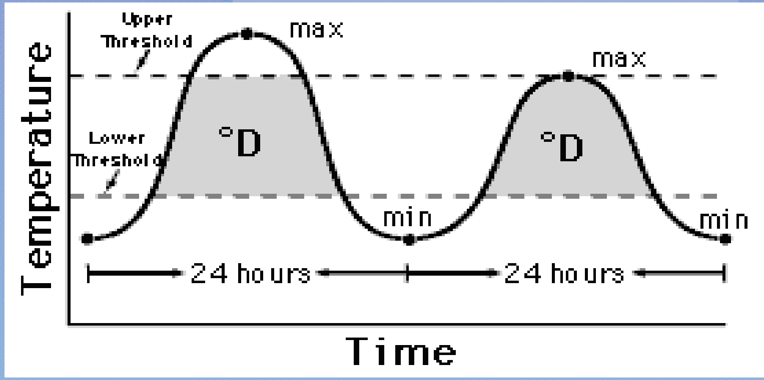
$$\frac{Tmax + Tmin}{2} - Tbase = degree\ days$$

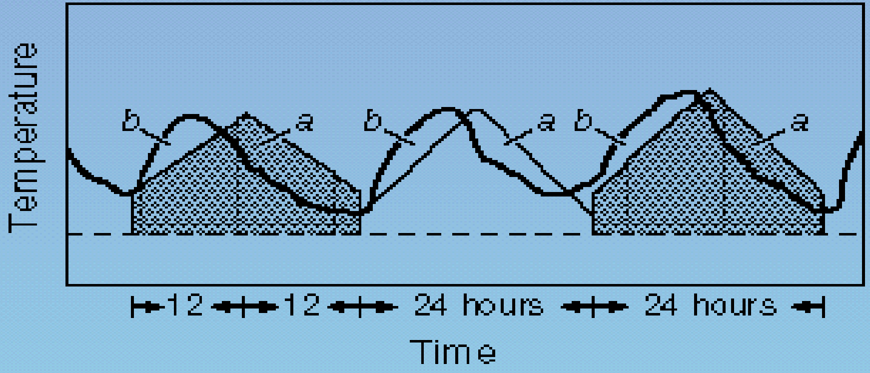
Phenology and degree-day concepts

- 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

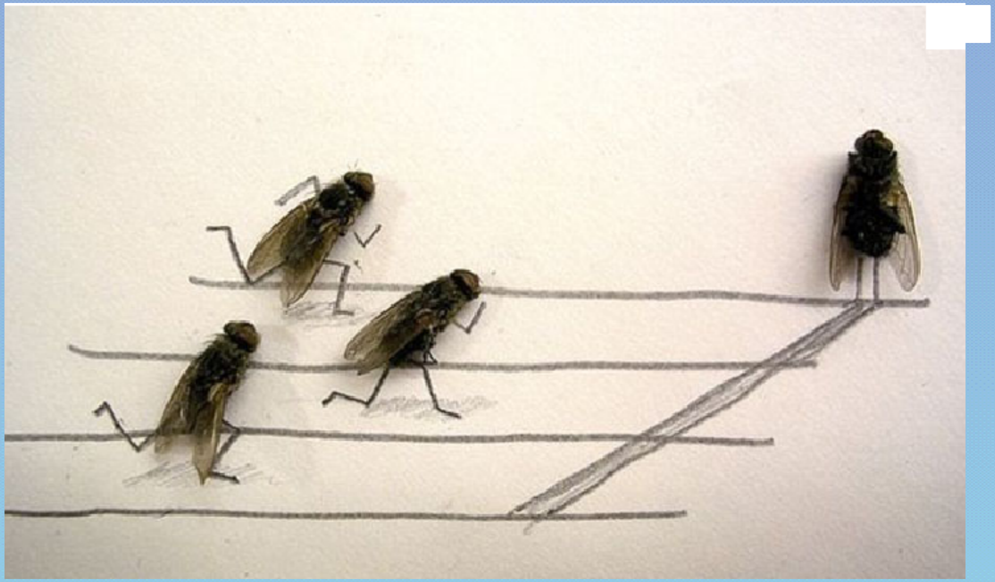
Degree-day calculations – method varies:
Simple avg: (daily max + min)/2 – low threshold



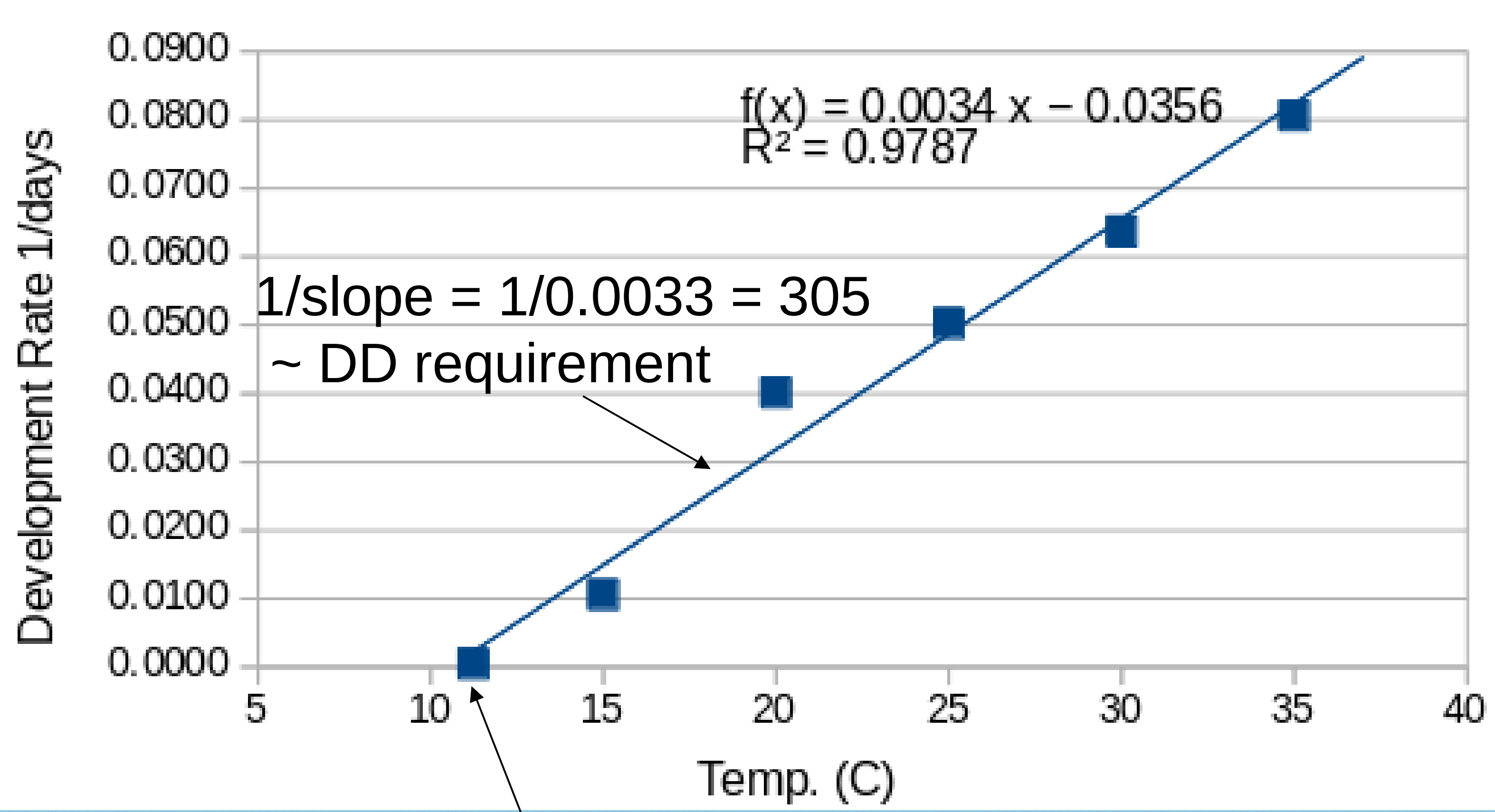


Single triangle compared with typical daily fluctuation

How fast are they going?



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



X-intercept = -a/b = 10.55 C = Tlow

Comparison of Degree-Day Calculation Methods

e. g. codling moth (Tlow=50, Tupper=88, method=s. sine, biofix to egg hatch=250 DDs)

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

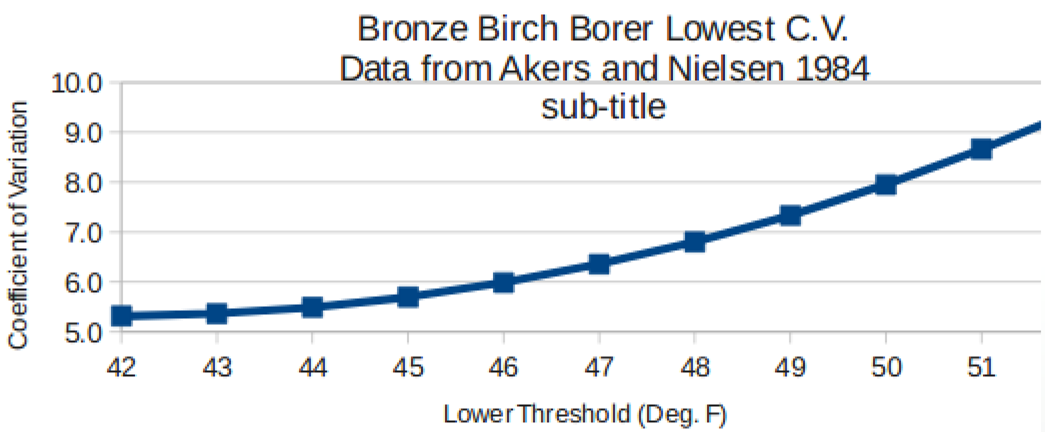
Field Data: Lowest C.V. Method of Finding Tlow (Arnold 1959)

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		**emerg.**		**Deg. C.**	**5.56**	**6.11**	**6.67**	**7.22**	**7.78**	**8.33**	**8.89**	**9.44**
Code	**year**	**DOY**	**Month-Day**	**Deg. F.**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**
Columbus	1981	150	05-30-81	**DDs (F):**	1058.1	987.1	918.9	853.4	790.8	731.6	676	623.5
(COLUMOH	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

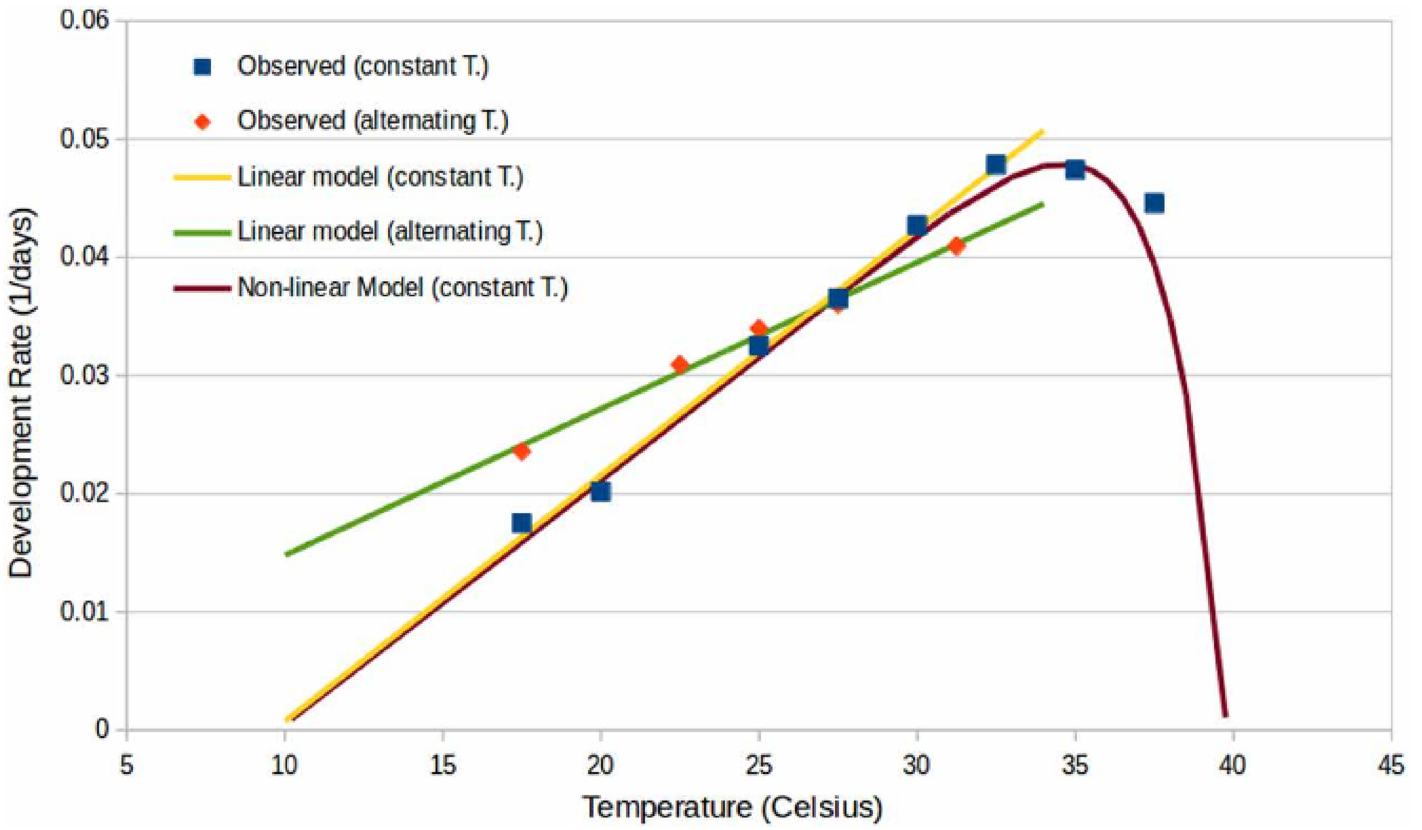
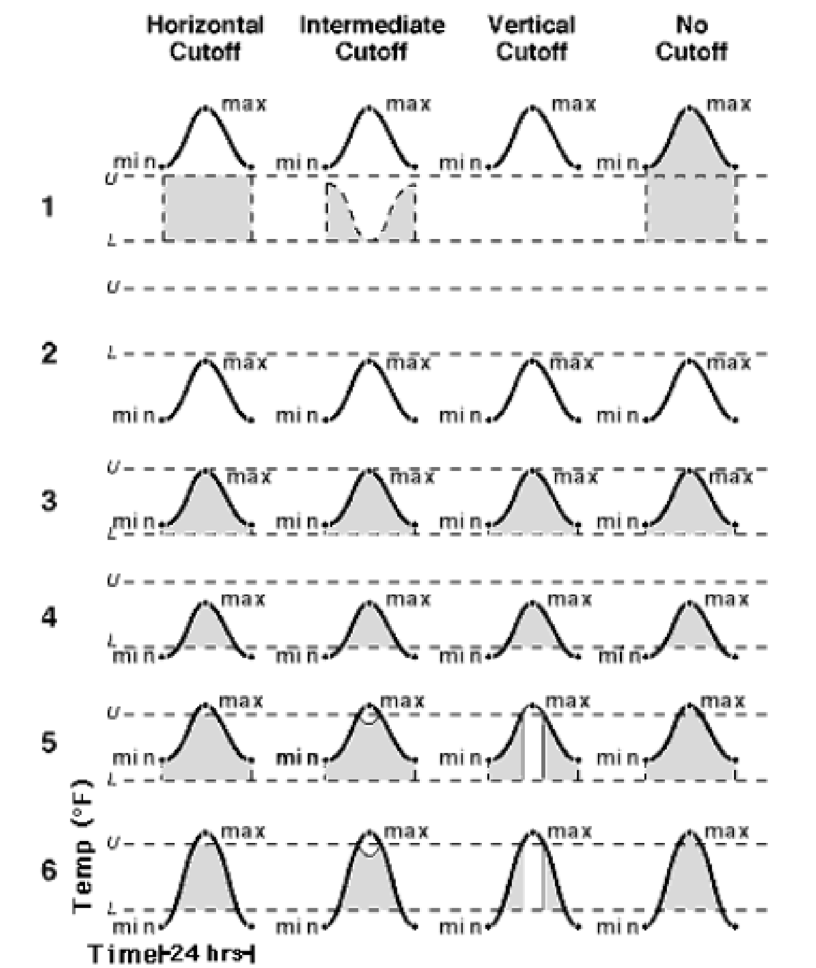


Figure 6 Linear and non-linear development rate models for cotton bollworm, *Helicoverpa amigera*, fitted using data from a laboratory study of egg-to-adult development at constant and alternating temperatures. Source: adapted from Mironidis and Savopoulou-Soultani (2008).

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

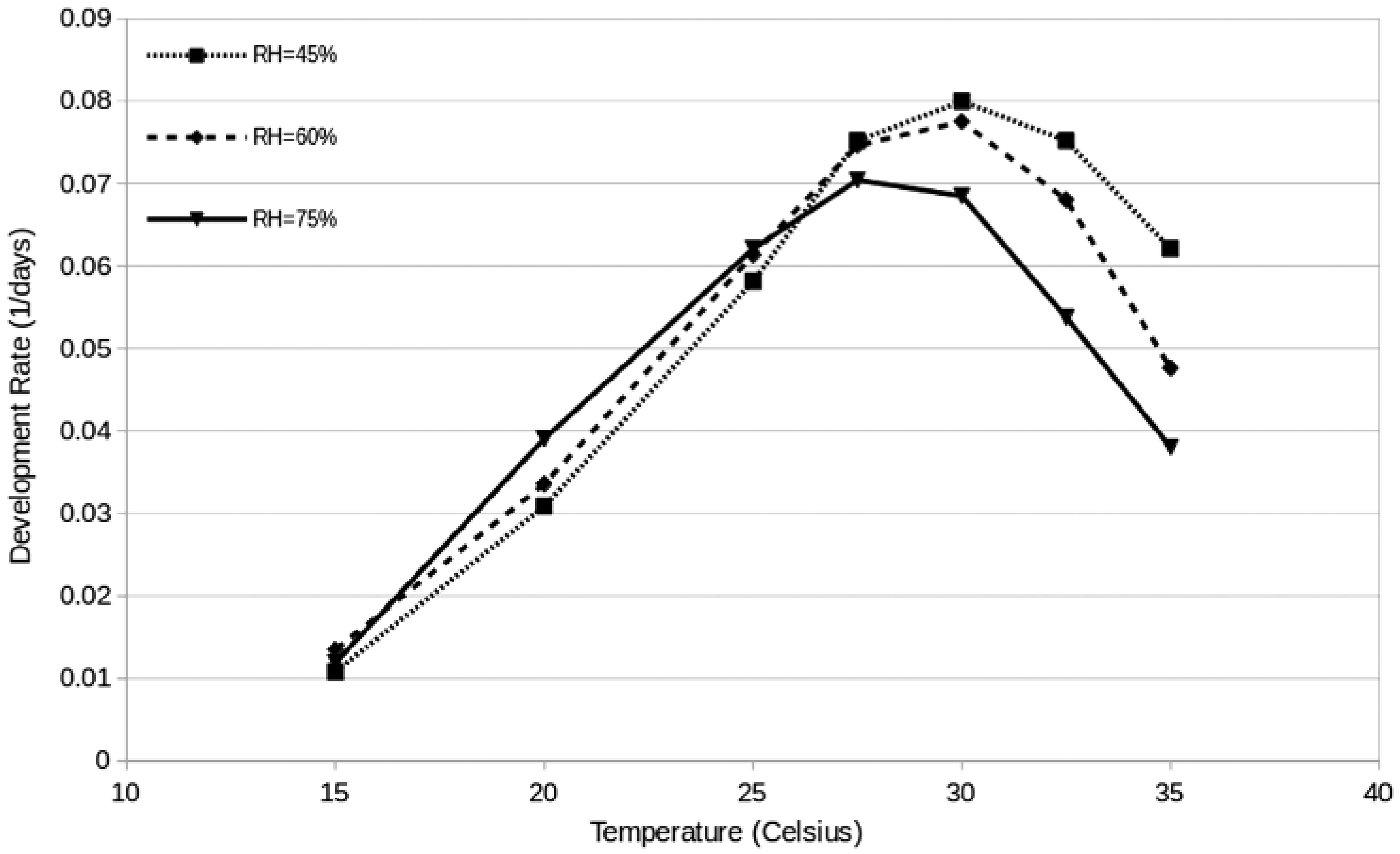


Figure 7 Plot depicting the effect of relative humidity (RH) on the temperature development rate curve for the scale insect *Phenacoccus solenopsis*. Source: data from Chen et al. (2015).

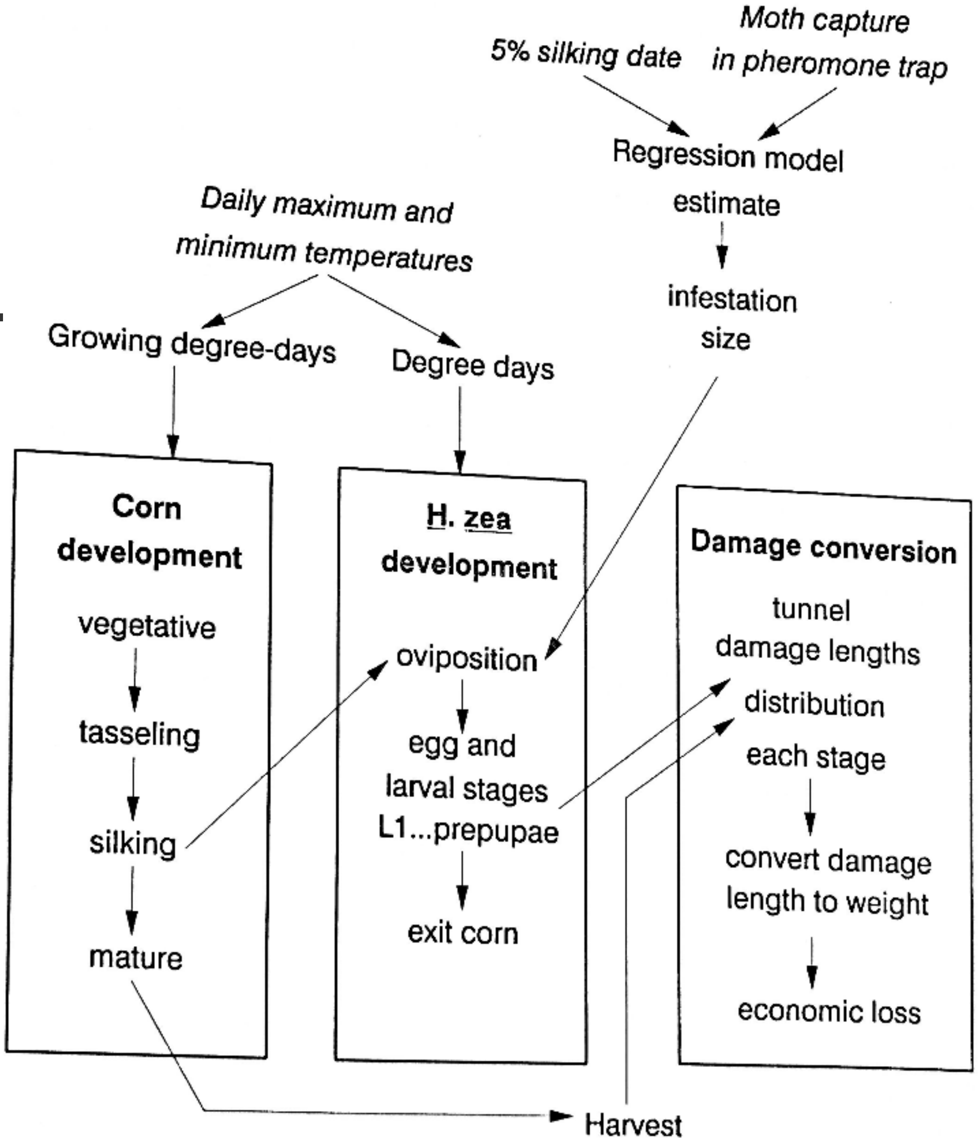
CROPTIME - Thermal time to maturity

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

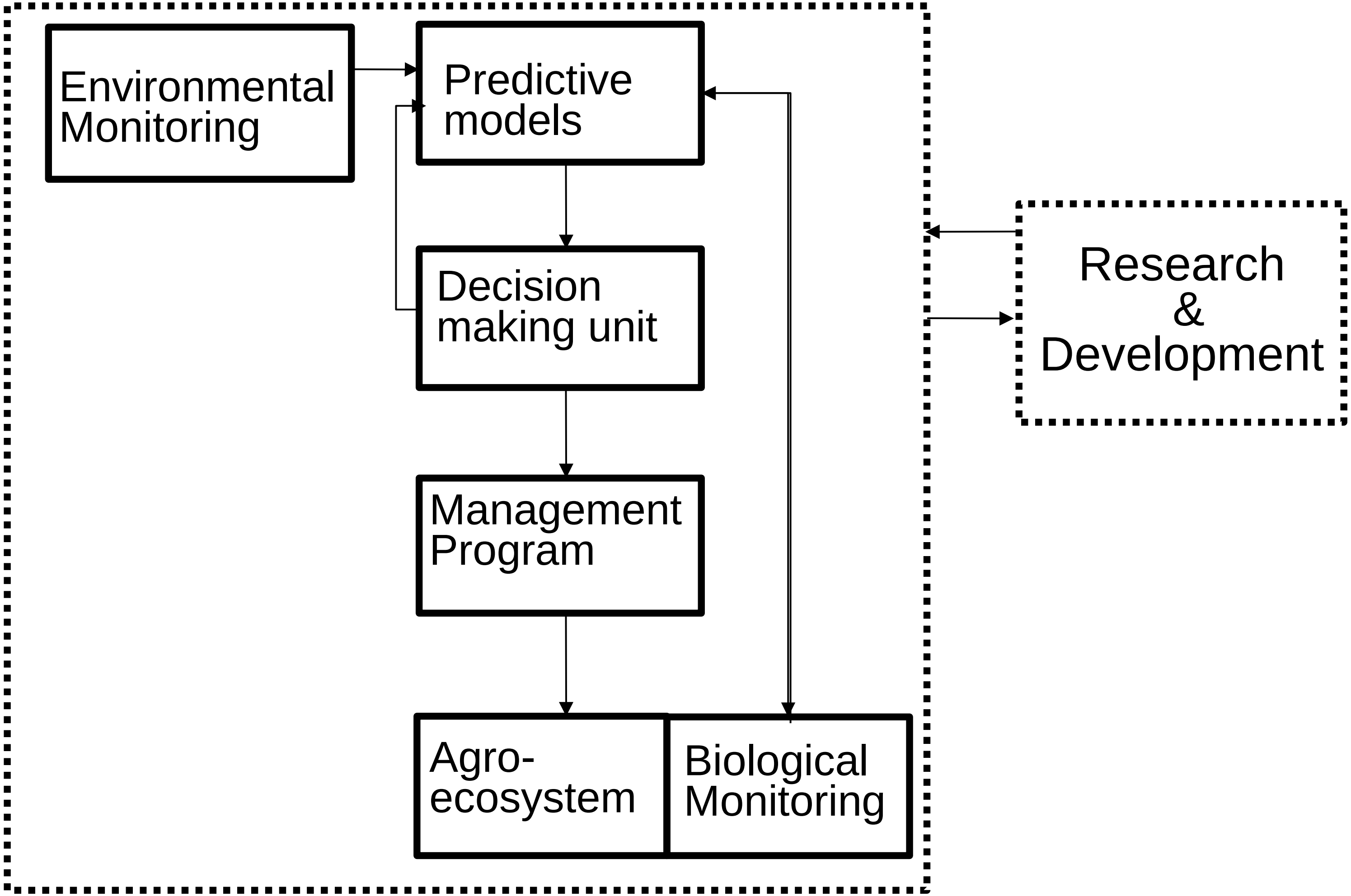
± 1-3 days accuracy

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

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

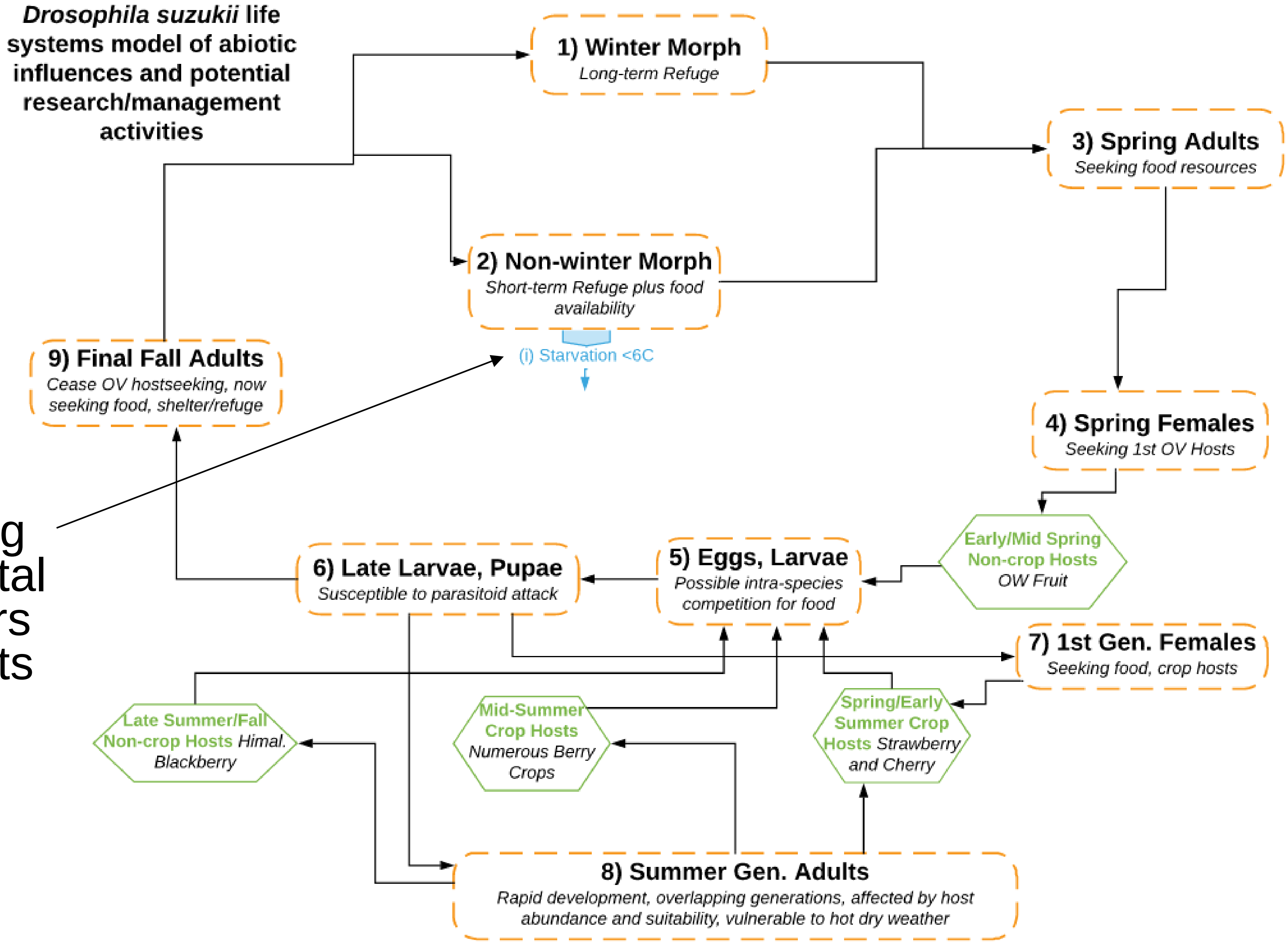
Leonard Coop and Brittany S. Barker, Oregon State University, USA

1 Introduction

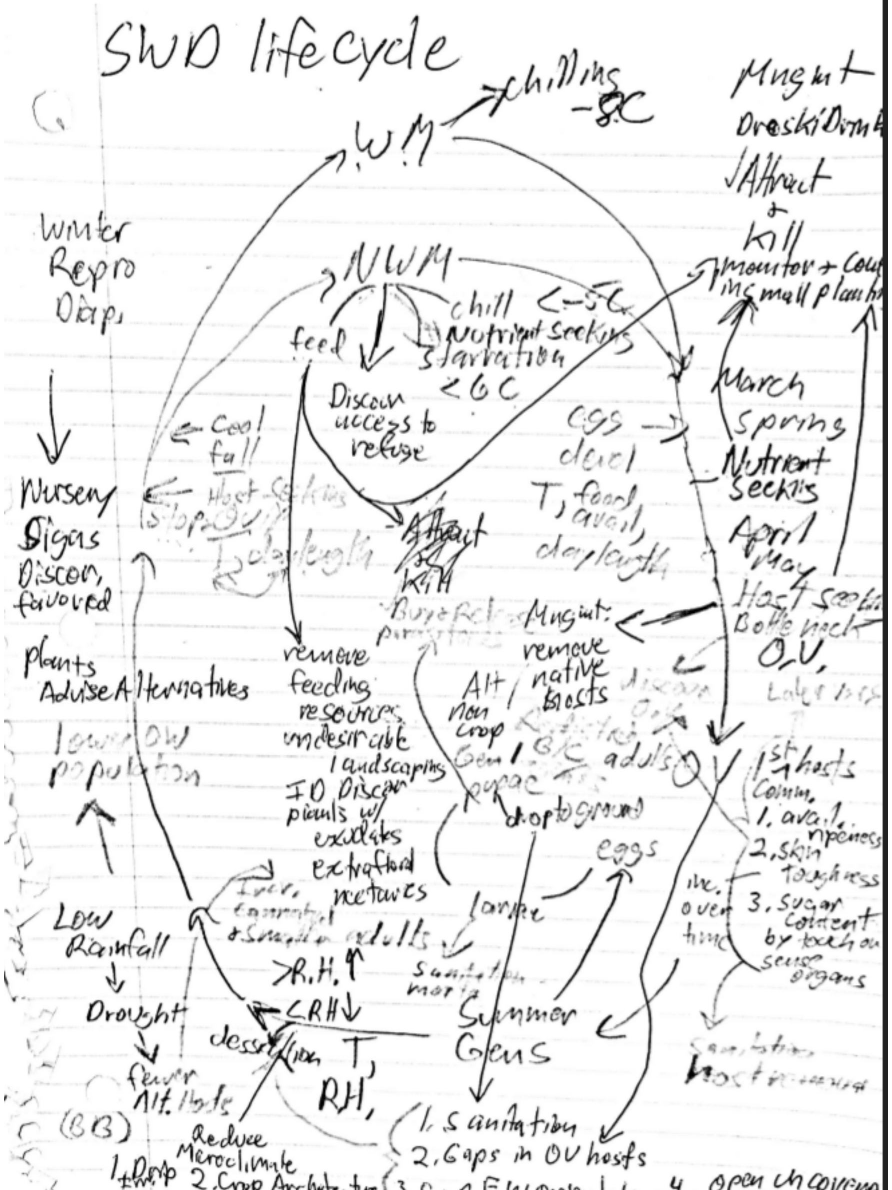
Rapid and widespread invasions of crop insect pests have had devastating impacts on crop performance and production, and represent one of the important and urgent challenges to the world's food supply (Pimentel et al., 2001; Bradshaw et al., 2016; Paini et al., 2016). Successfully managing and preventing 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.,

Step 1.
Draw the organism's life cycle

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



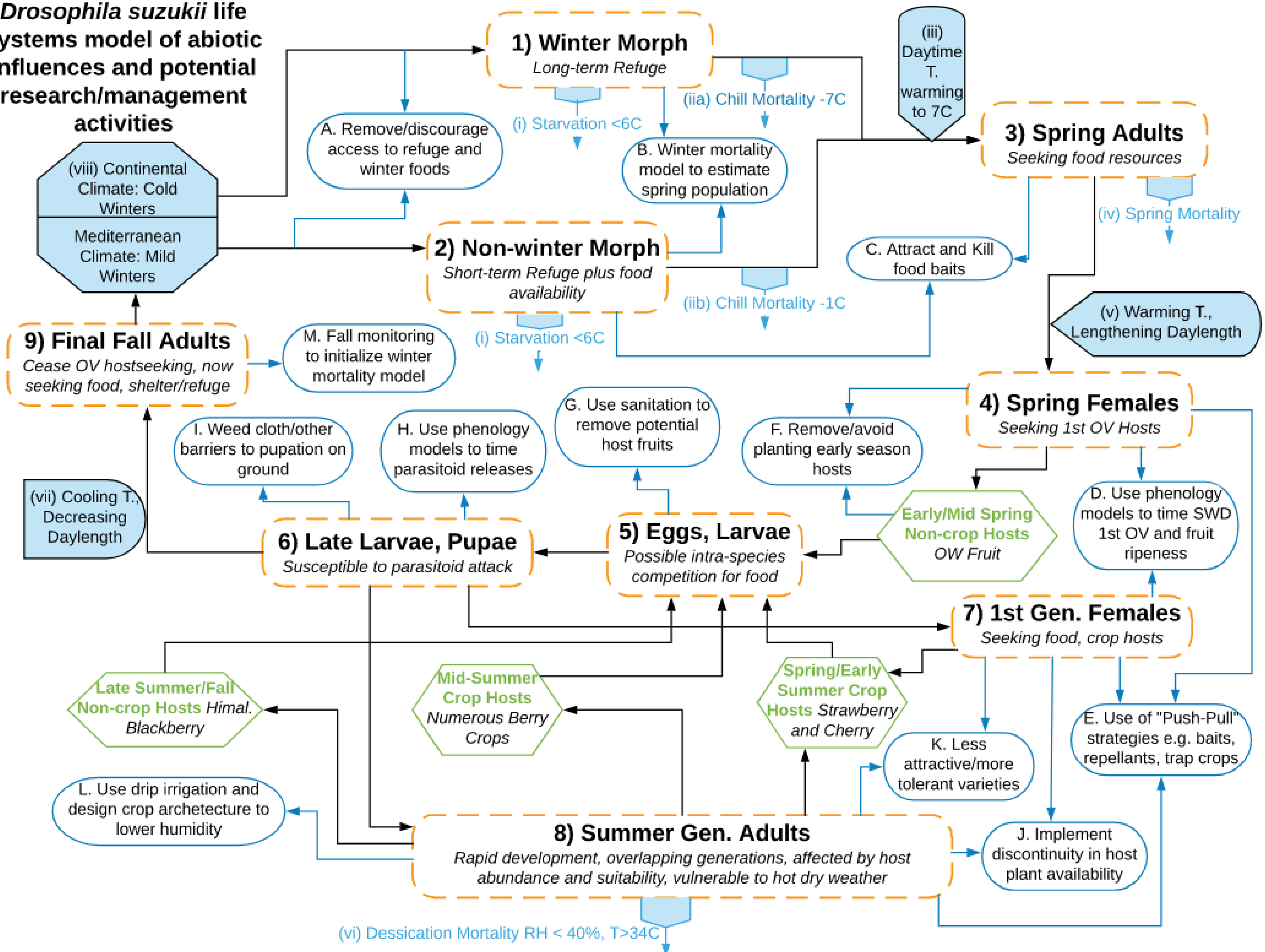
My first draft of SWD conceptual model (dont expect your first version To be the last)



Step 3. Add management practices

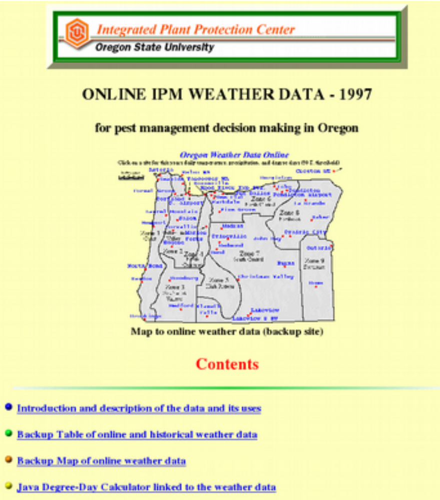
Steps 4&5. Document and Refine

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

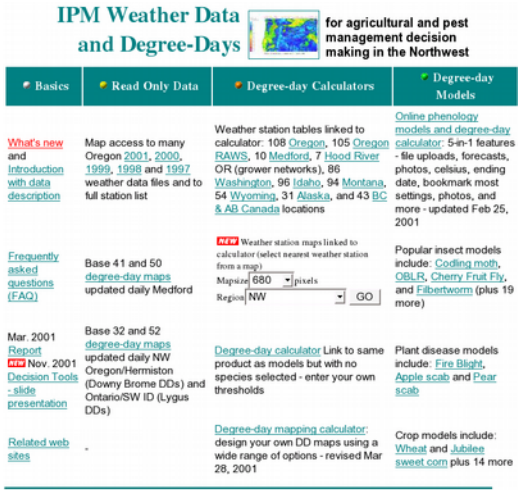


History of USPEST.ORG home page

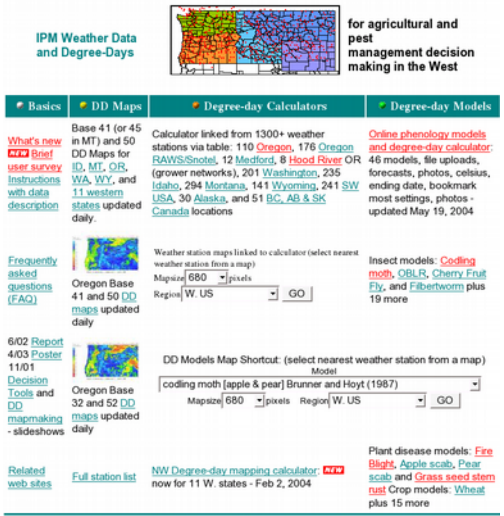
1997



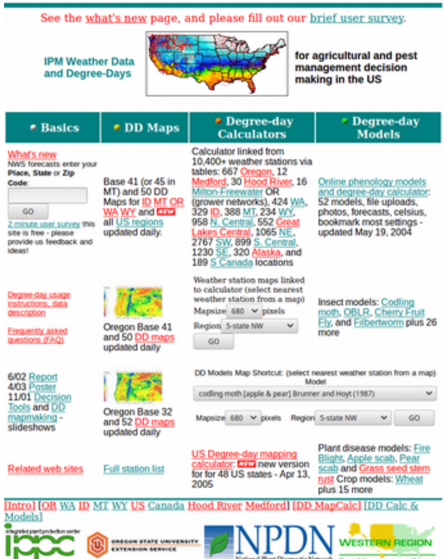
2001



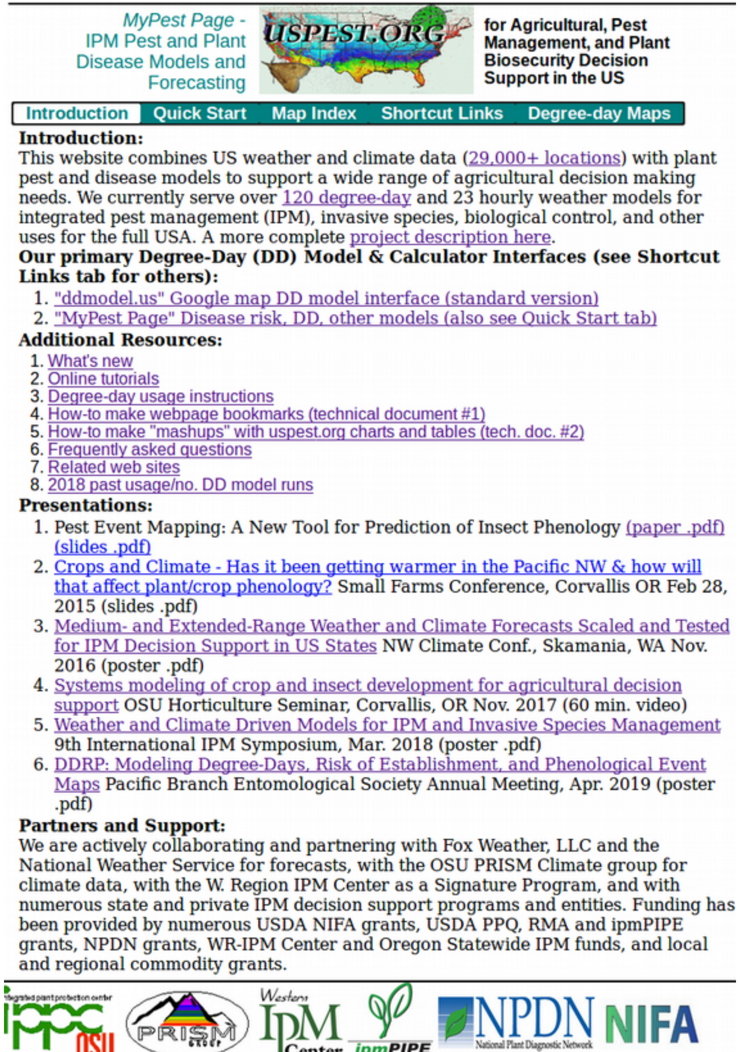
2004



2007



2010 - 2019



MyPest Page - IPM Pest and Plant Disease Models and Forecasting

USPEST.ORG

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:

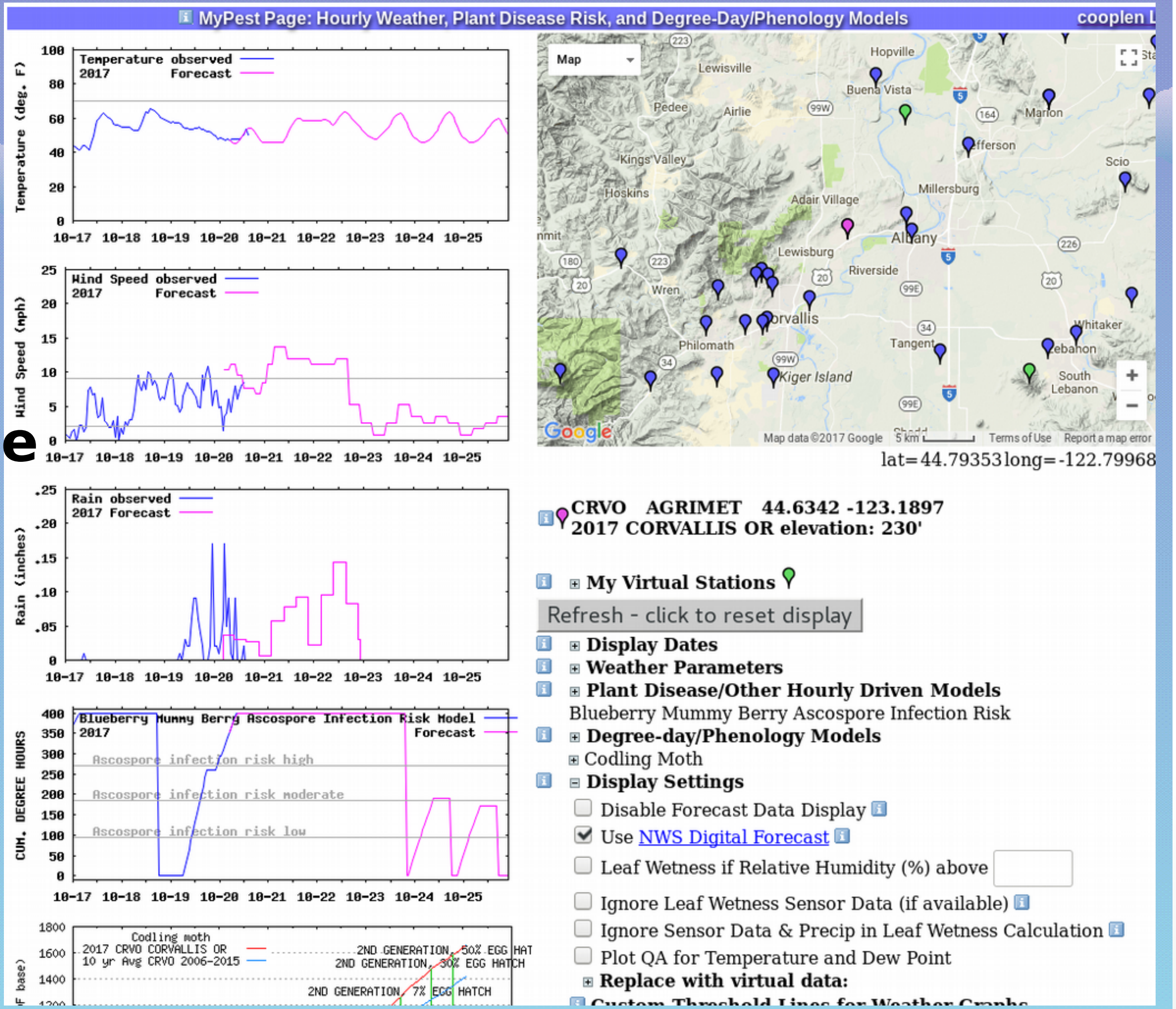
1. Pest Event Mapping: A New Tool for Prediction of Insect Phenology (paper .pdf) (slides .pdf)
2. Crops and Climate - Has it been getting warmer in the Pacific NW & how will that affect plant/crop phenology? Small Farms Conference, Corvallis OR Feb 28, 2015 (slides .pdf)
3. Medium- and Extended-Range 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:

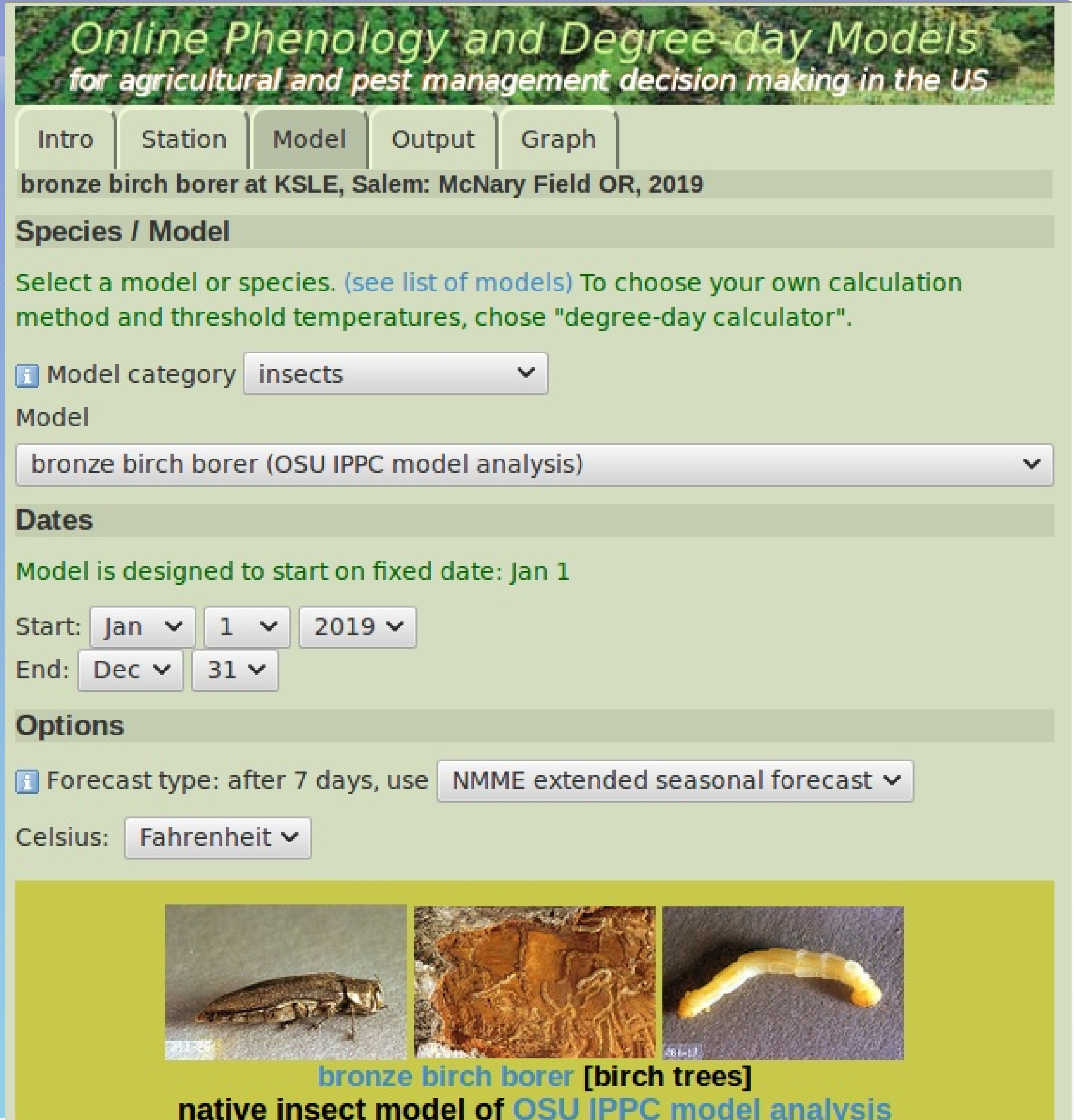
We are actively collaborating and partnering with Fox Weather, LLC and the National Weather Service for forecasts, with the OSU PRISM Climate group for climate data, with the W. Region IPM Center as a Signature Program, and with numerous state and private IPM decision support programs and entities. Funding 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 grants.

USPEST.ORG
Mypest page

- 150 models
  - 128 phenology/ degree-day
  - 22 hourly driven e.g. plant disease Infection risk
- 29,000 weather stations



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



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.

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
CRVO
Choose... **Enable** ☒

Station 2
AW810105
Choose... **Enable** ☒

Station 3
AU650
Choose... **Enable** ☐

Save Stations

- 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: both table and graph

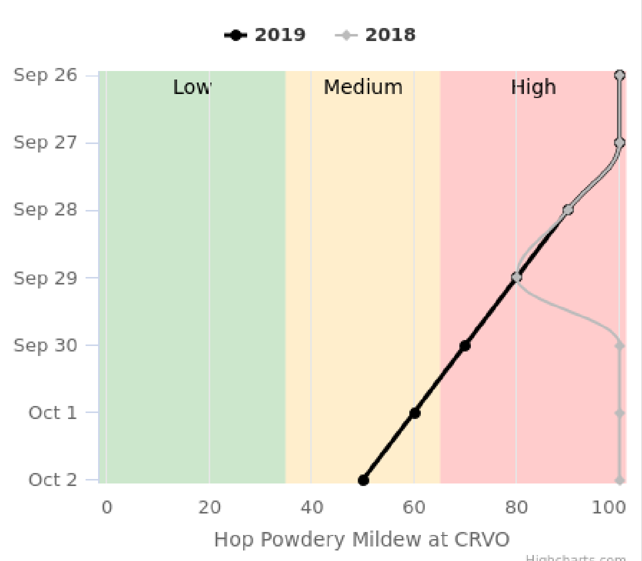
From no-reply@uspest.org
Subject **Pest Risk Index Report**
To Len Coop

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

Hop Powdery Mildew (susceptible varieties)

Hops Powdery Mildew Risk for Station CRVO
latest index online

	2019		2018	
Date	**Risk index**	**Risk class**	**Risk index**	**Risk class**
Sep 26	100	High	100	High
Sep 27	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



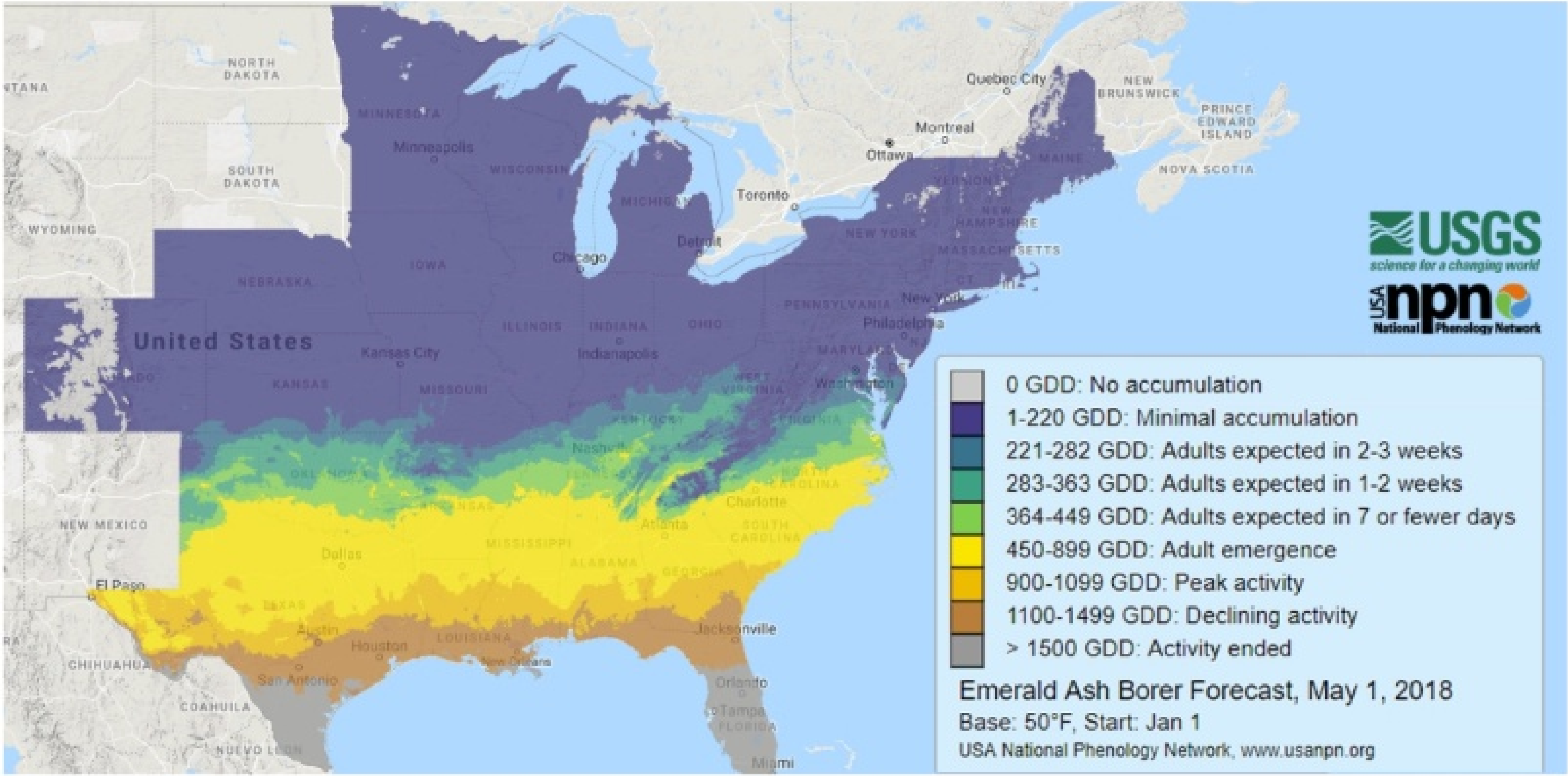
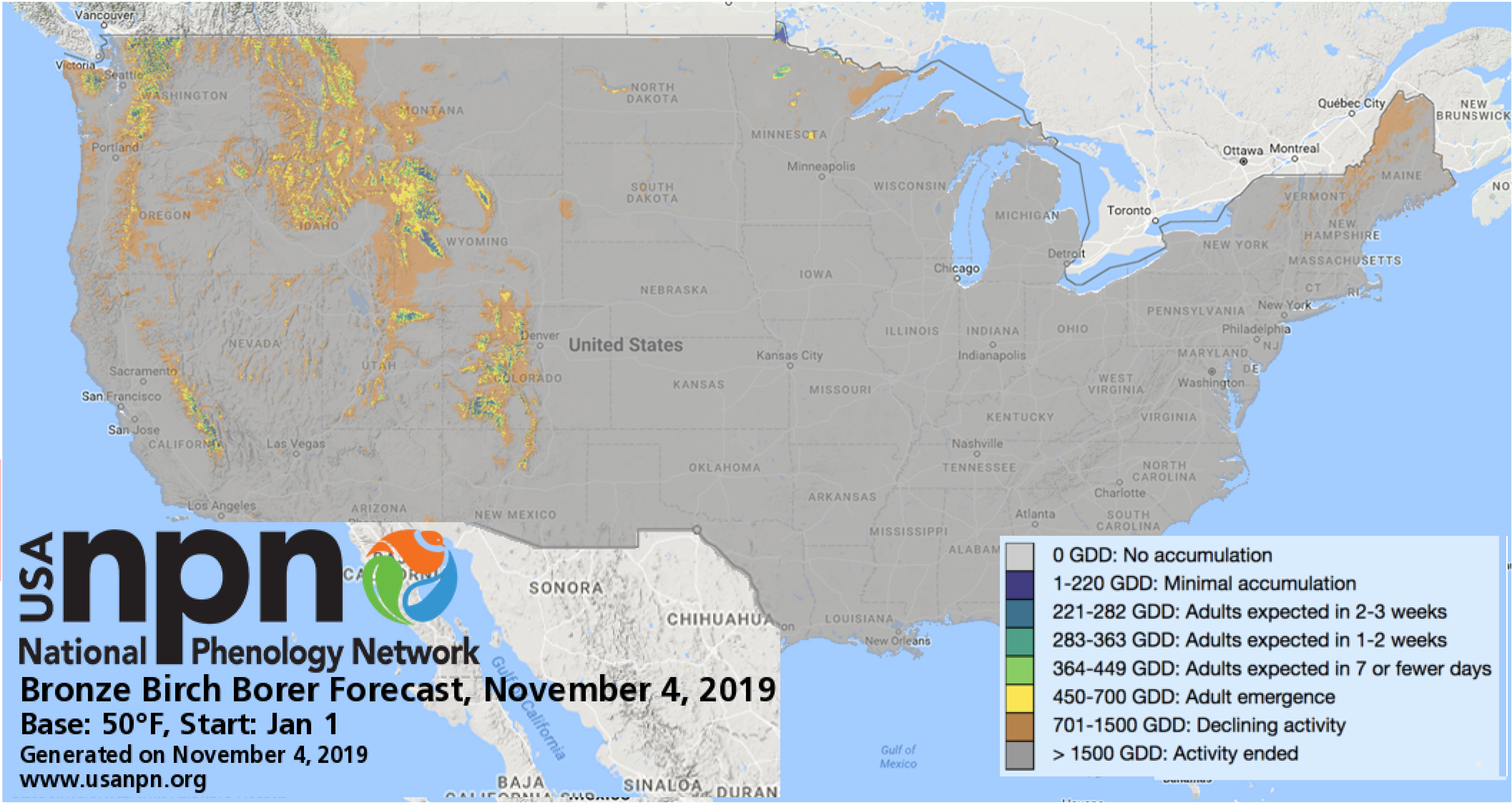


Figure 1. Pheno Forecast map for emerald ash borer for May 1, 2018. Colors indicate the status of adult emergence. The status of a location is determined by comparing the local GDD accumulation to a published heat accumulation threshold for the life cycle stage.



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
0 GDD: No accumulation
1-220 GDD: Minimal accumulation
221-282 GDD: Adults expected in 2-3 weeks
283-363 GDD: Adults expected in 1-2 weeks
364-449 GDD: Adults expected in 7 or fewer days
450-700 GDD: Adult emergence
701-1500 GDD: Declining activity
> 1500 GDD: Activity ended
United States
Vancouver
Victoria
Seattle
WASHINGTON
Portland
OREGON
IDAHO
MONTANA
WYOMING
NORTH DAKOTA
SOUTH DAKOTA
MINNESOTA
Minneapolis
WISCONSIN
MICHIGAN
Detroit
Chicago
Toronto
Ottawa
Montreal
Québec City
NEW BRUNSWICK
MAINE
VERMONT
NEW HAMPSHIRE
MASSACHUSETTS
NEW YORK
CT
RI
New York
PENNSYLVANIA
Philadelphia
NJ
MARYLAND
DE
Washington
NEBRASKA
IOWA
ILLINOIS
INDIANA
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WEST VIRGINIA
VIRGINIA
KENTUCKY
Nashville
TENNESSEE
NORTH CAROLINA
Charlotte
SOUTH CAROLINA
Atlanta
MISSISSIPPI
ALABAMA
ARKANSAS
MISSOURI
Kansas City
KANSAS
OKLAHOMA
NEW MEXICO
ARIZONA
COLORADO
Denver
UTAH
NEVADA
Sacramento
San Francisco
San Jose
CALIFORNIA
Las Vegas
Los Angeles
SONORA
CHIHUAHUA
LOUISIANA
New Orleans
SINALOA
Gulf of California
Gulf of Mexico
BAJA CALIFORNIA SUR

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 (:

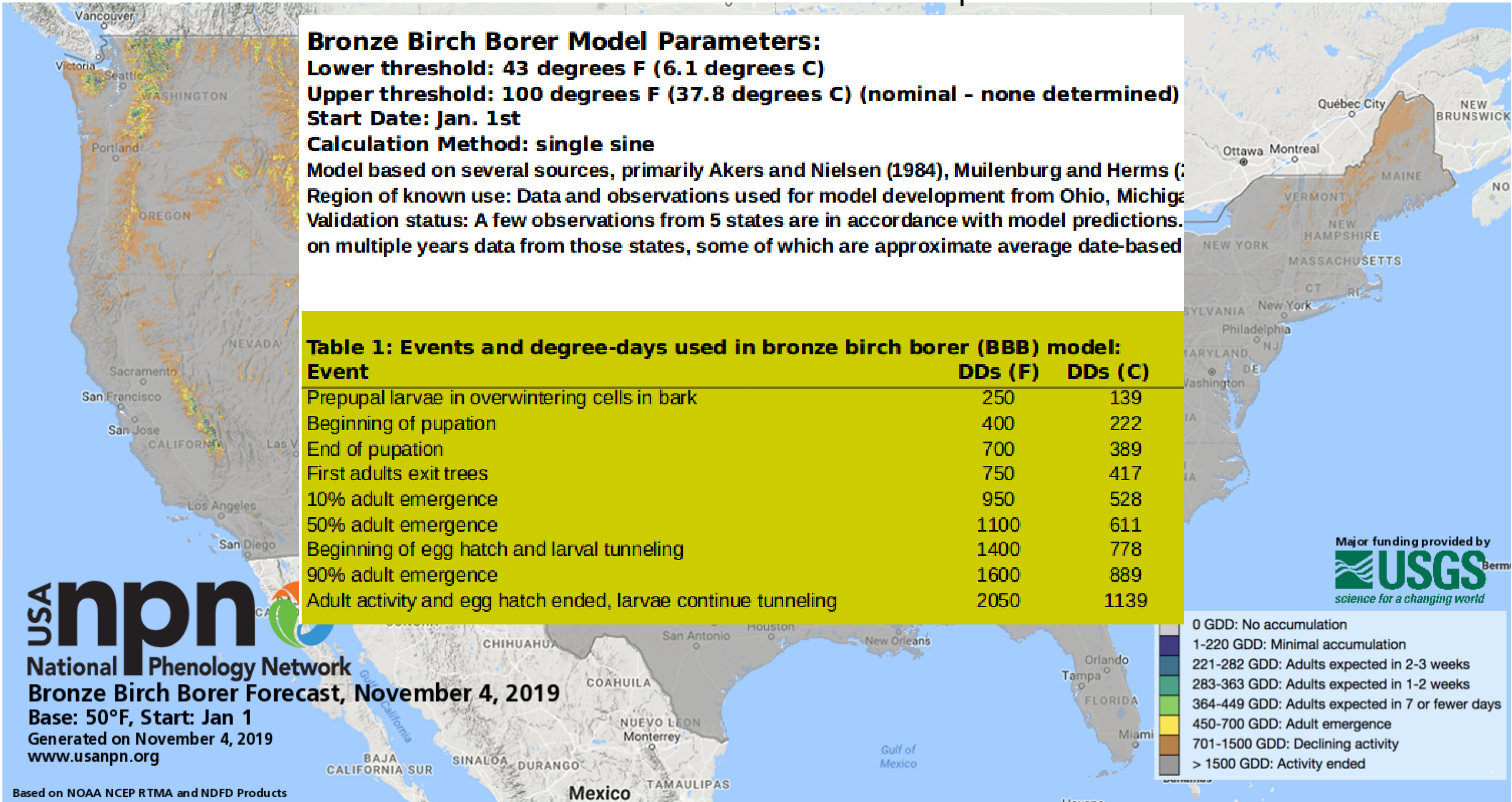
Region of known use: Data and observations used for model development from Ohio, Michiga

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



Chemeketa CC – Intro to Phenology Models

Questions? Ready for Exercises?

Len Coop
Assistant Professor (Practice)
Hort. Dept. and Integrated Plant Protection Center