Modeling Tools for Vegetable Pest Surveillance and Management

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PNVA Conference | November 15, 2023

Oregon State University
Oregon IPM Center

Outline

1) Early detection of invasive species
2) Decision-support models
   - Phenology and establishment risk
   - Models at USPest.org
3) Future work and key take-aways

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SAFEGUARDING AMERICA'S LANDS AND WATERS FROM INVASIVE SPECIES

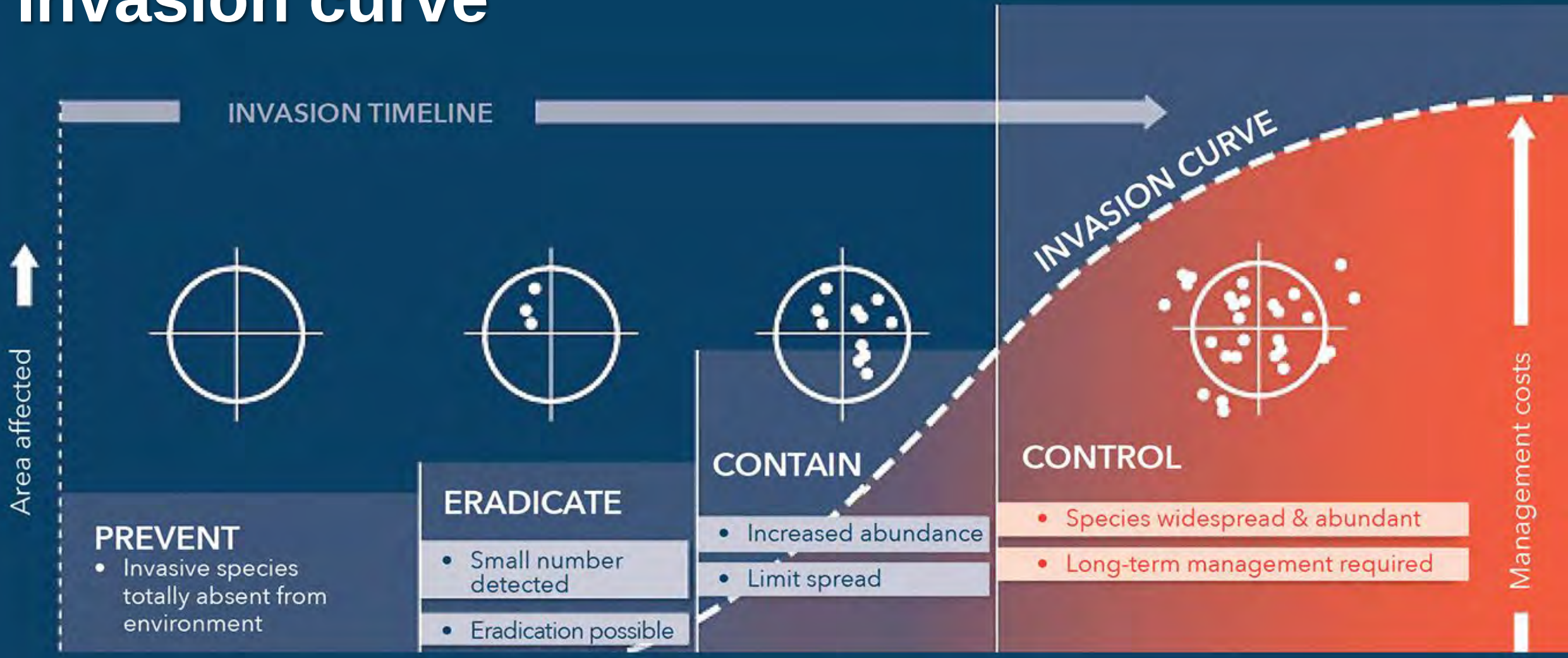
A National Framework for Early Detection and Rapid Response

The U.S. Department of the Interior (2016)

Biological Invasion, Early Detection & Rapid Response

Biological invasion is the process by which non-native species breach biogeographic barriers and extend their range (McGraw-Hill 2003). In the context of biological invasion, early detection is the process of surveying for, reporting, and verifying the presence of a non-native species, before the founding population becomes established or spreads so widely that eradication is no longer feasible. Rapid response is the process that is employed to eradicate the founding population of a non-native species from a specific location.

Invasion curve

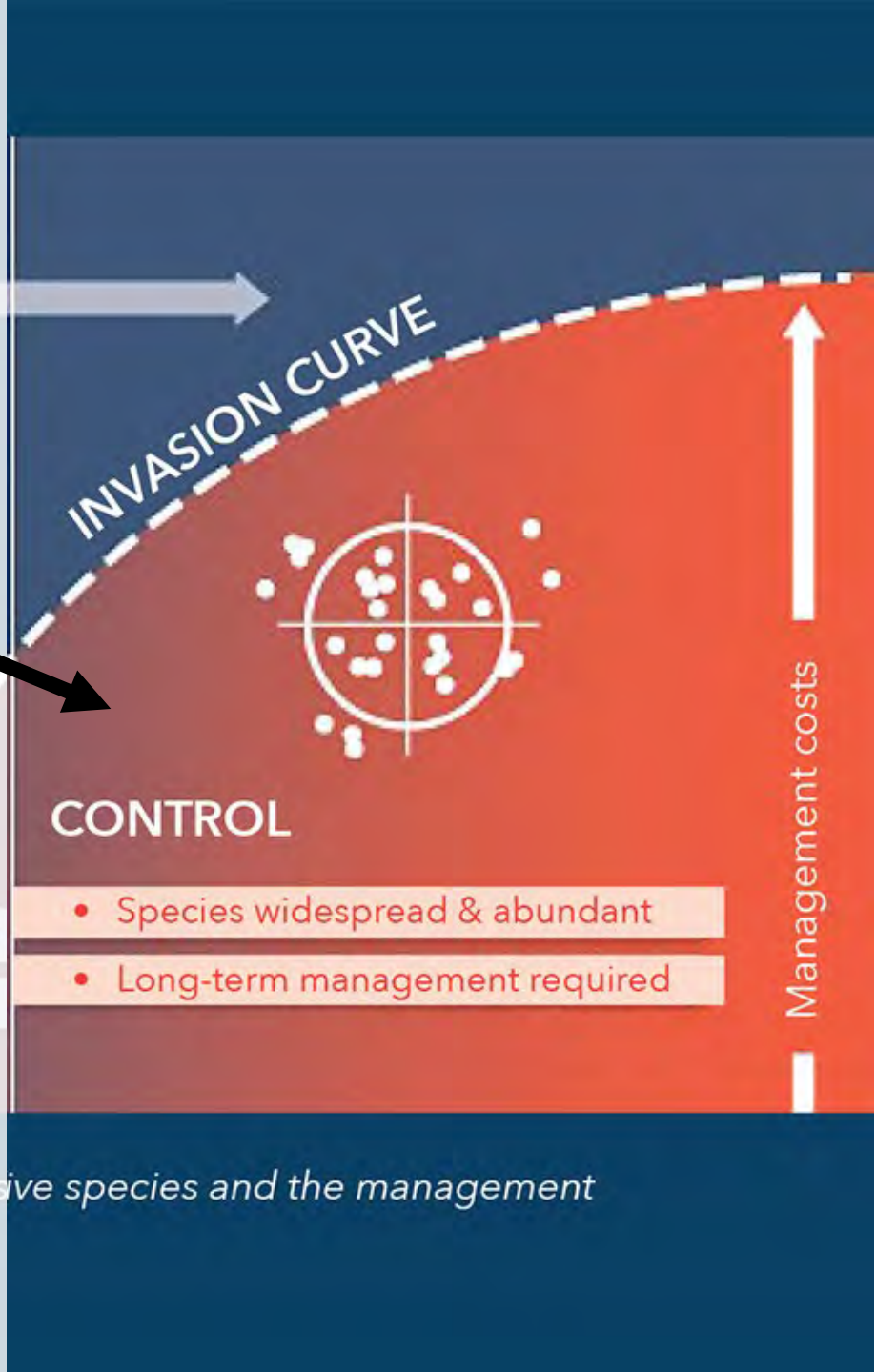


The invasion curve describes the arrival and spread of a new invasive species and the management actions required at each stage

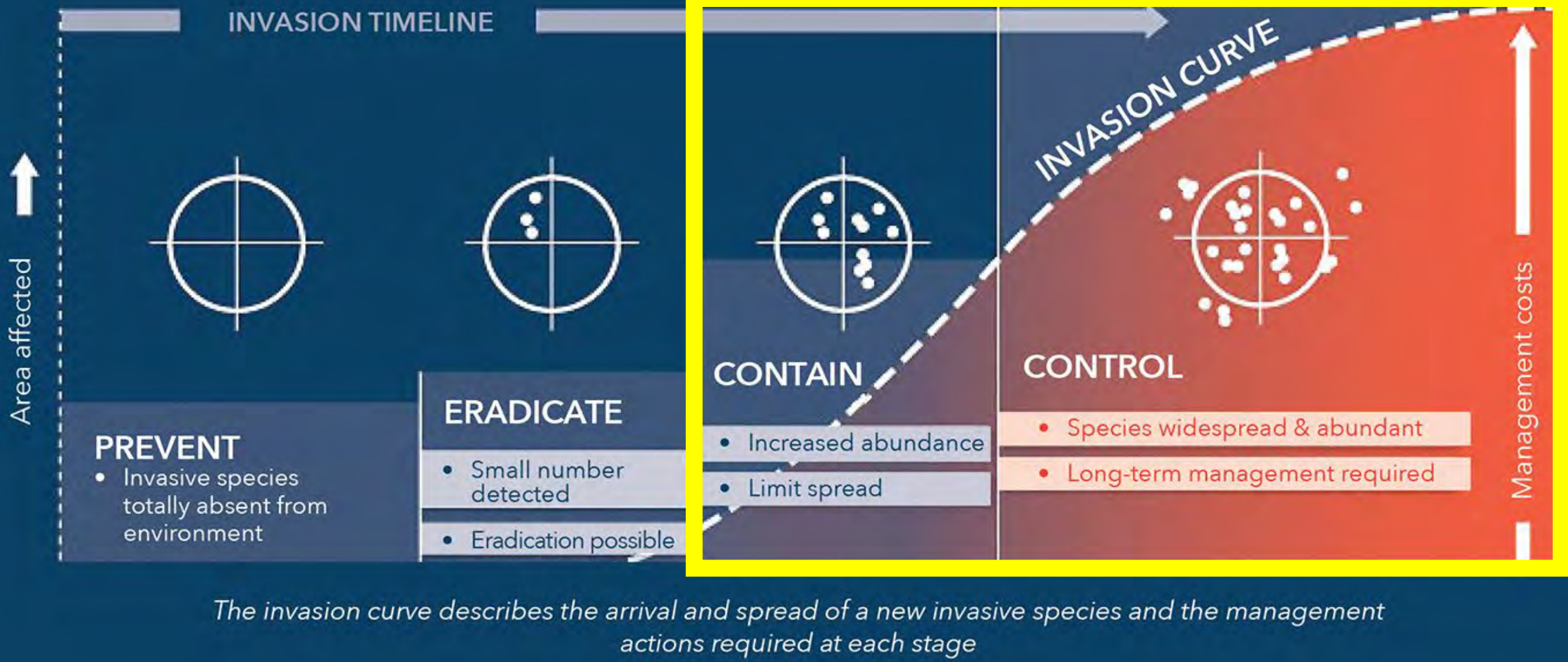
Credit: Invasive Species Council

Some examples for PNW (native to Eurasia)

1. Cabbage maggot (*D. radicum*)
2. Seedcorn maggot (*D. platura*)
3. Diamondback moth (*P. xylostella*)
4. Carrot rust fly (*P. rosae*)



Early detection & rapid response helps avoid ... *THIS*

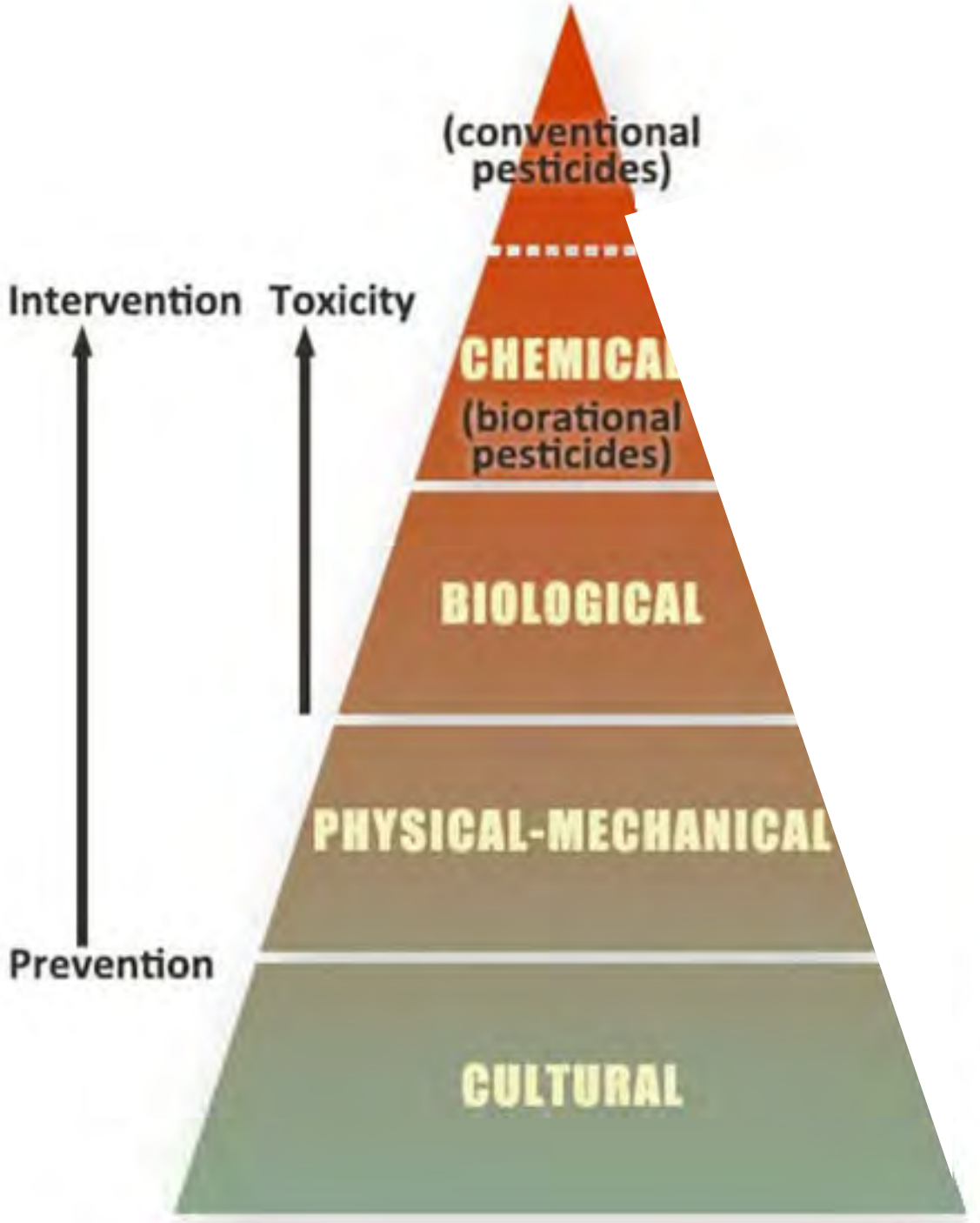


The invasion curve describes the arrival and spread of a new invasive species and the management actions required at each stage

Credit: Invasive Species Council

Also eliminates or reduces need for toxic chemicals

Integrated Pest Management (IPM) pyramid



Source: López-Uribe Lab

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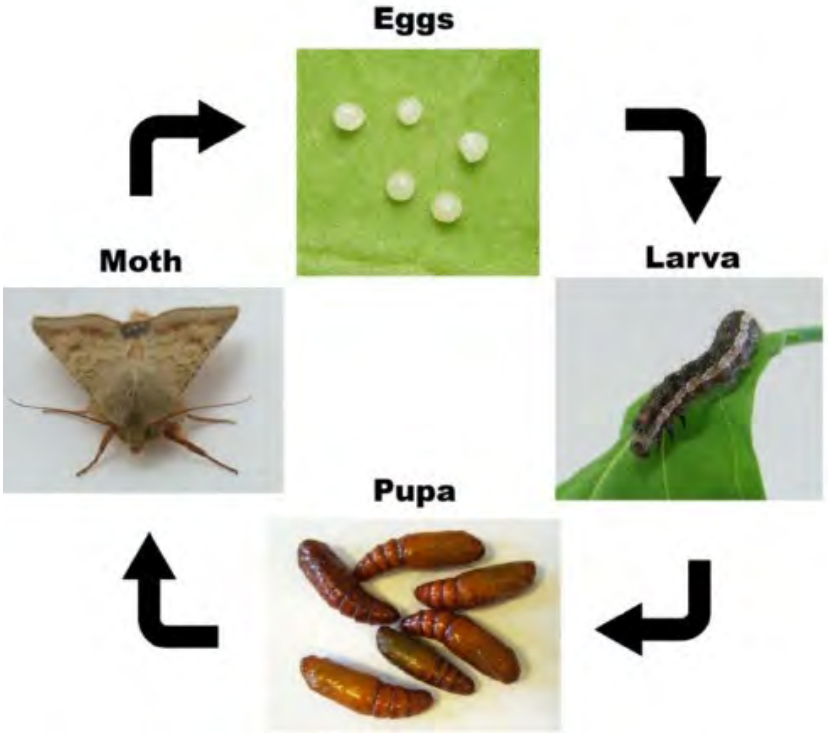
Models help prevent & manage invasions

Phenology models

- Predict development and activities
- Know ***when*** to look
- Install detection devices on time, timely monitoring and management



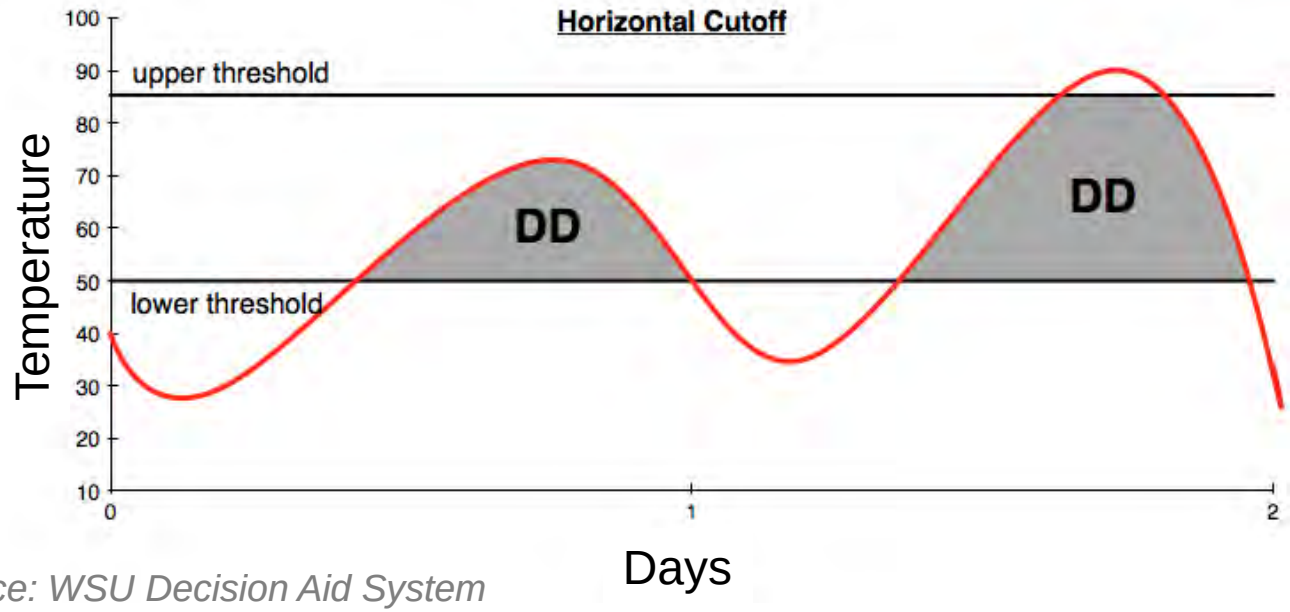
Old World bollworm
(*Helicoverpa armigera*)

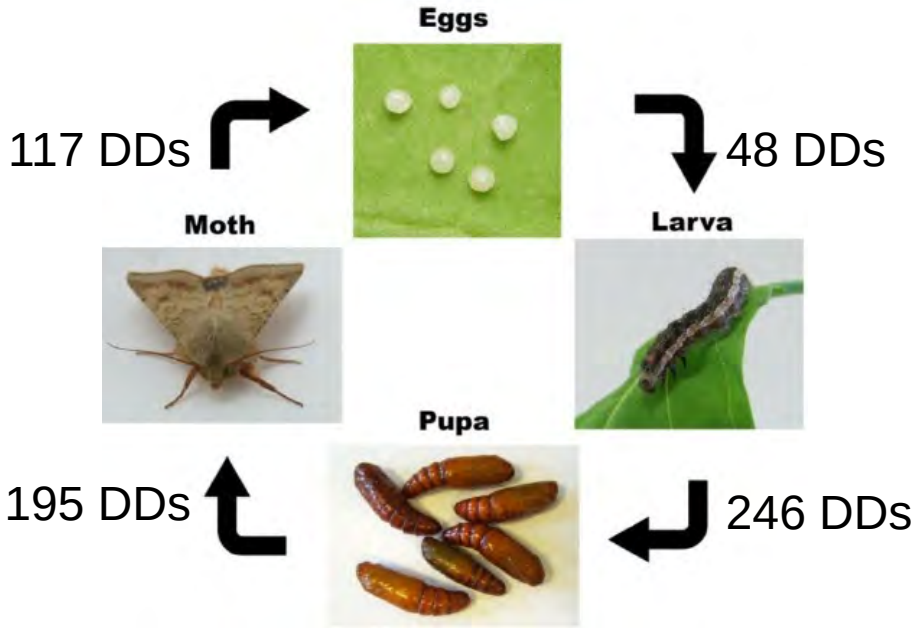
- Not established in U.S.
- Attacks >180 species inc. corn, soybean, tomato

Phenology models 101

Many phenology models calculate degree-days (DDs)

- Unit of heat whereby temperature is integrated over time
- DDs start/stop accumulating at temperature thresholds
- A certain number of DDs are required to reach each life stage





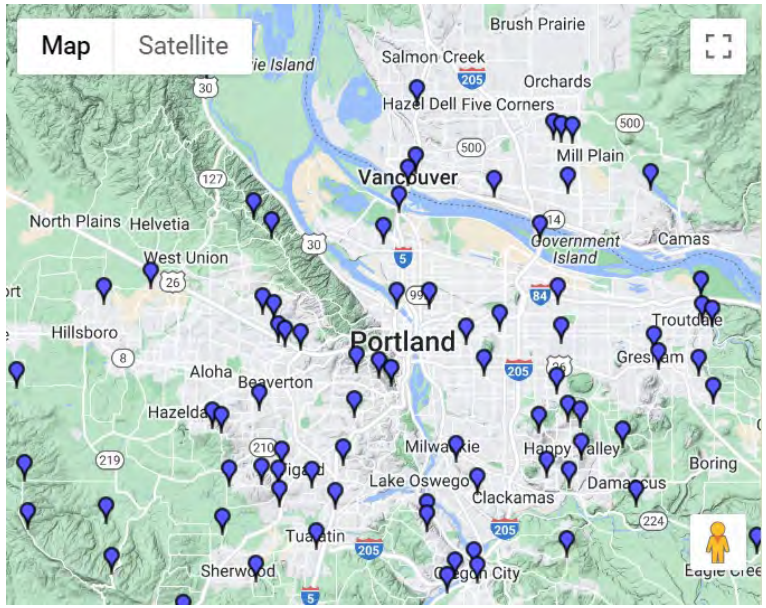
Source: WSU Decision Aid System

Phenology models 101

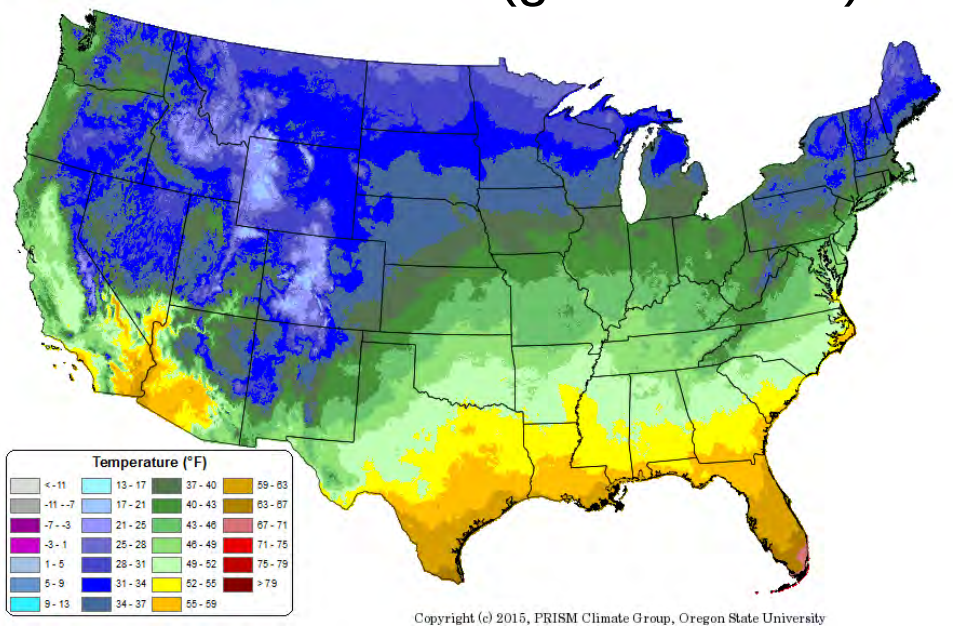
Degree-day model inputs

1. Information on target species (e.g., temperature thresholds)
2. Daily temperature (max, min) data

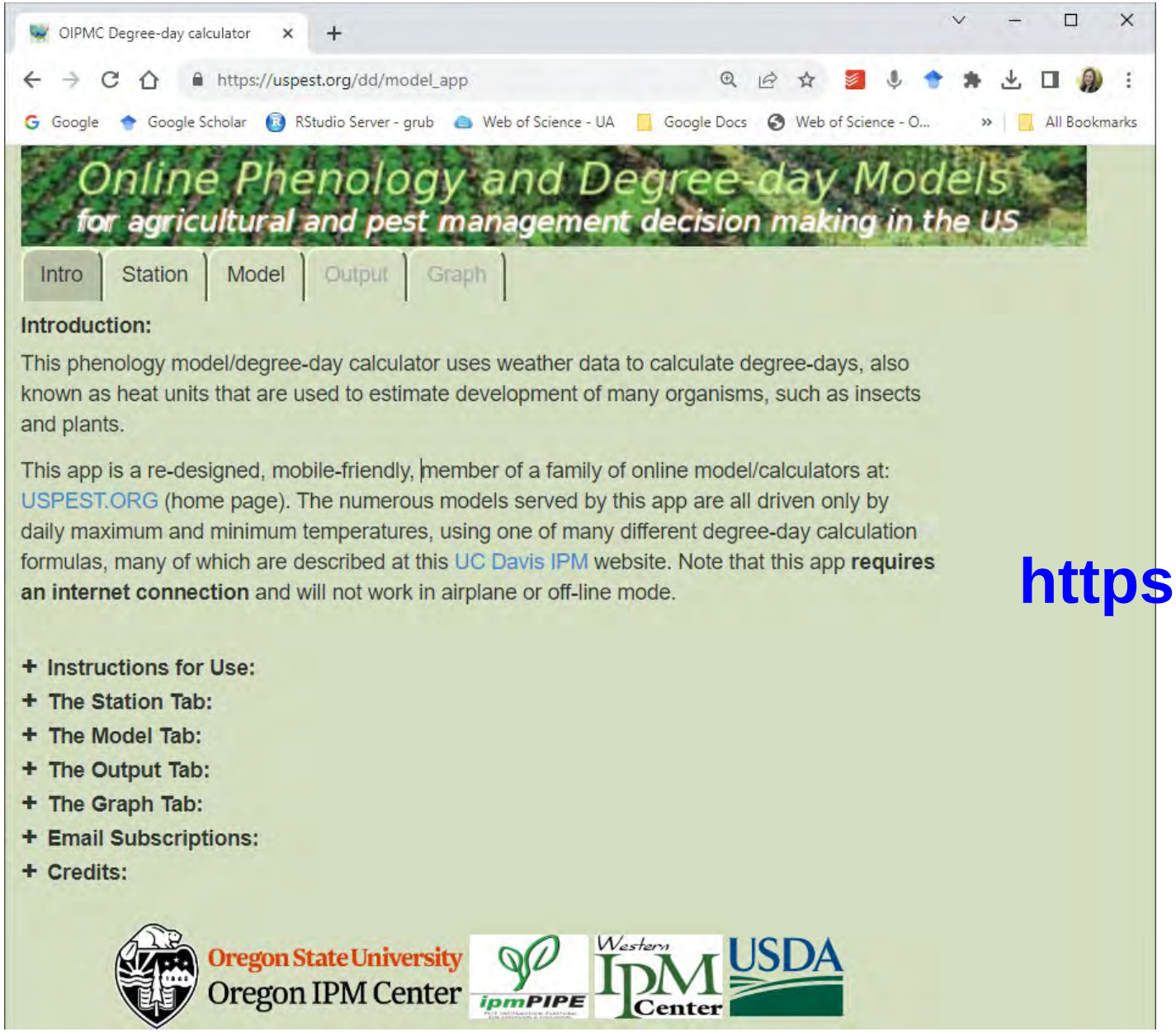
Single site (weather station)



Area-wide (gridded data)



Single-site phenology models at USPest.org



Quick stats

- Open access
- Total of **144** models (crops, disease, insects, weeds..)
- **28** invasive insect models
- **32,000+** weather stations

https://uspest.org/dd/model_app

Single-site phenology models

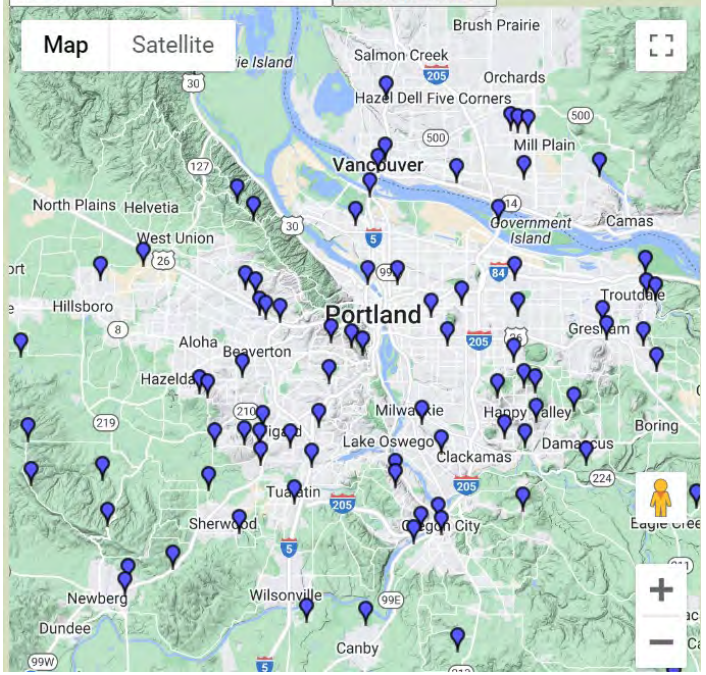
Intro | Station | Model | Output | Graph

Weather Station

Currently selected: *(none)*

You can search for stations by city, other place name, ZIP code, or station code.

97223 | search for stations



(1) Choose station

Intro | Station | Model | Output | Graph

old world bollworm at F5278, FW5278 Portland OR, 2023

Species / Model

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

Model category: invasive insects

Model:

old world bollworm (H armig.) (OSU OIPMC model analysis)

Dates

Model is designed to start on fixed date: Jan 1

Start: Jan 1 2023

End: Dec 31

Options

Forecast type: after 7 days, use NMME extended seasonal forecast

Temperature scale: Fahrenheit

Next

That's all the necessary input. From here, you can study the model details below, or go to the "Output" and "Graph" tabs for your model output.

Helicoverpa armigera [cotton, corn, others]
invasive insect model of OSU OIPMC model analysis

(2) Enter dates & options

(3) View outputs (tabular or graph)

https://uspest.org/dd/model_app

Intro | Station | Model | Output | Graph

old world bollworm at F5278, FW5278 Portland OR, 2023

Model Inputs

☐ show model inputs table

Date Comparison

☐ show Date Comparison table

Model Output

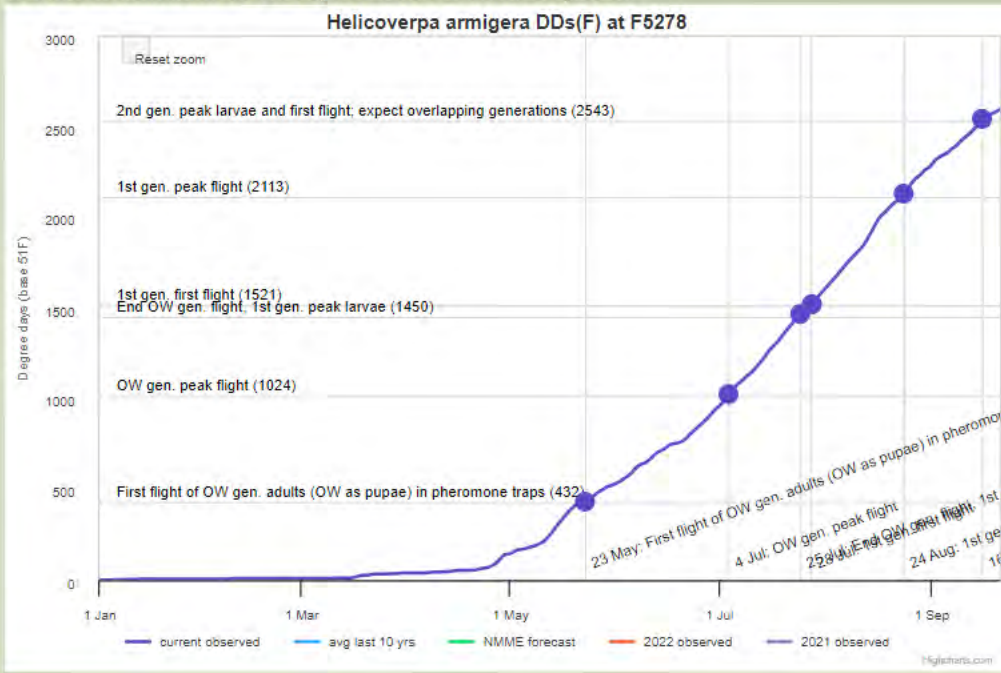
☐ show full table

Temperatures (and degree-days) are in F; rain in inches.

date	max	min	rain	DDs today	DDs cumu	QA	events
1-1	47	37	0.00	0.0	0		* START *
5-23	65	44	0.00	5.3	433		First flight of OW gen. adults (OW as pupae) in pheromone traps
7-4	94	56	0.00	24.0	1026		OW gen. peak flight
7-25	80	62	0.00	20.0	1469		End OW gen. flight, 1st gen. peak larvae
7-28	86	58	M	20.7	1523	Hx	1st gen. first flight
8-24	92	55	0.01	22.5	2134		1st gen. peak flight
9-16	85	56	0.00	19.5	2546		2nd gen. peak larvae and first flight; expect overlapping

Intro | Station | Model | Output | Graph

old world bollworm at F5278, FW5278 Portland OR, 2023



Models help prevent & manage invasions

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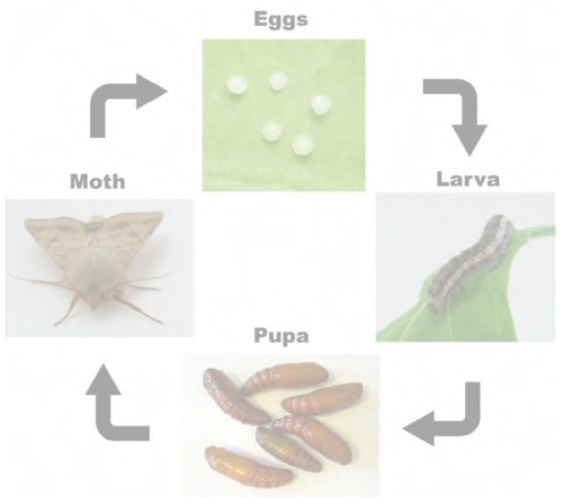
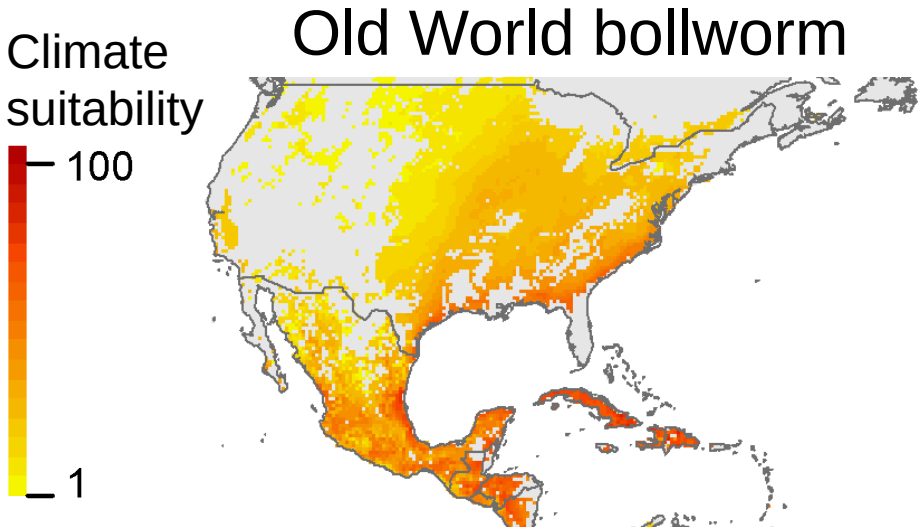


Establishment risk models

- Identify areas with suitable climates and hosts
- Know ***where*** to look
- Focus surveillance efforts in high risk areas



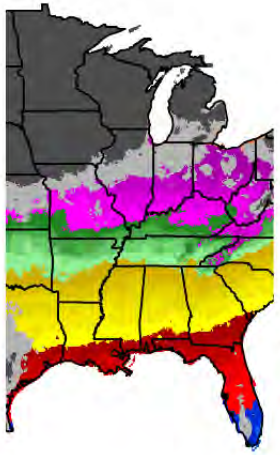
Kriticos et al. (2015) PLoS ONE

Spatial models at USPest.org

- DDRP: open-source spatial modeling tool at USPest.org
- Combines **phenology** and **establishment risk** modeling
- Produces maps (not single sites) for 16 invasive insect species
- Applications: primarily for surveillance, but management for some species

README.md

An introduction to DDRP



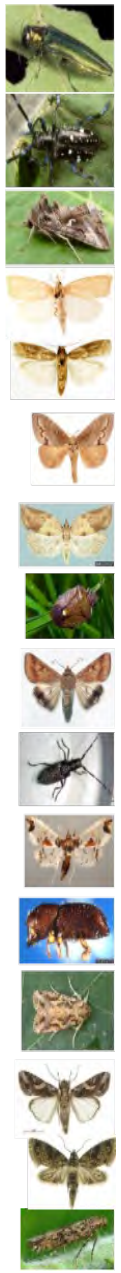
Degree-
Days,
Risk, and
Phenological
event
mapping

Oregon State University
Oregon IPM Center

Brittany Barker, Len Coop, Tyson Wepprich, Gericke Cook, and Dan Upper

https://uspest.org/CAPS

Spatial models run every 2-3 days; forecasts available at uspest.org/CAPS



Species	Common Name	Status in CONUS
Agrilus planipennis	Emerald ash borer	Present
Anoplophora glabripennis	Asian longhorned beetle	Present
Autographa gamma	Silver Y moth	Not pres.
Chilo suppressalis	Asiatic rice borer	Not pres.
Cryptoblabes gnidiella	Christmas berry webworm	Not pres.
Dendrolimus pini	Pine-tree lappet moth	Not pres.
Epiphyas postvittana	Light brown apple moth	Present
Eurygaster integriceps	Sunn pest	Not pres.
Helicoverpa armigera	Old world bollworm	Not pres.
Monochamus alternatus	Japanese pine sawyer beetle	Not pres.
Neoleucinodes elegantalis	Small tomato borer	Not pres.
Platypus quercivorus	Oak ambrosia beetle	Not pres.
Spodoptera littoralis	Egyptian cottonworm	Not pres.
Spodoptera litura	Common or cotton cutworm	Not pres.
Thaumatotibia leucotreta	False codling moth	Not pres.
Tuta absoluta	Tomato leaf miner	Not pres.

Spatial models run every 2-3 days; forecasts available at uspest.org/CAPS

Vegetable pests

	Species	Common Name	Status in CONUS
	*Agrilus planipennis*	Emerald ash borer	Present
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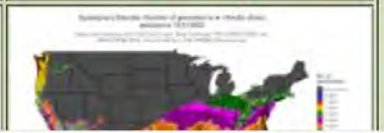
	***Tuta absoluta***	**Tomato leaf miner**	**Not pres.**

Home page and directory of selected **D**egree-**D**ay, establishment **R**isk, and **P**est event maps (**DDRP**)

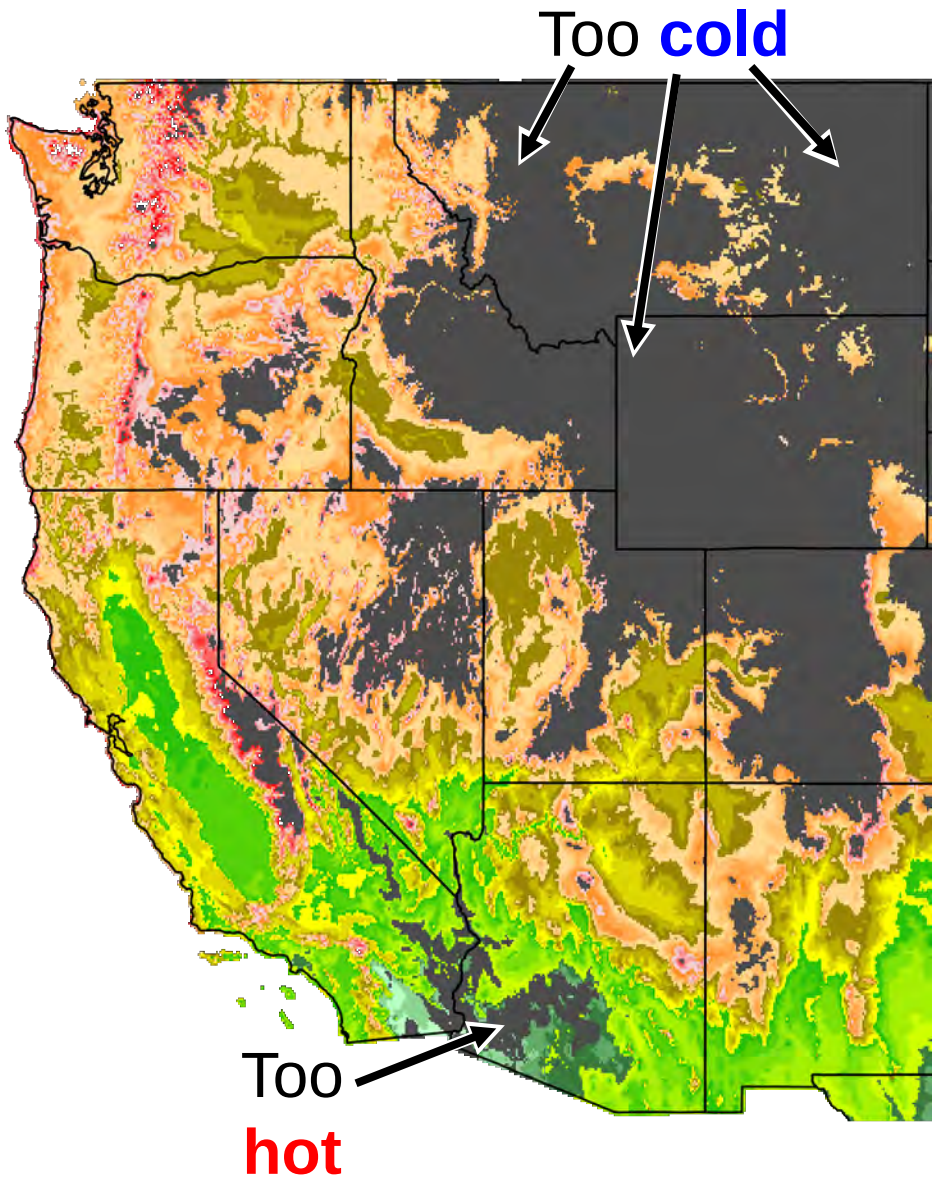
Summary An improved understanding of *where* an invasive species could potentially establish as well as *when* developmental stages are expected to occur have the potential to support and dramati pest surveillance and management decisions. We have developed a new spatial modeling platform that integrates mapping of phenology and climatic suitability in real-time to provide timely and co and when invasive insect species could potentially invade the conterminous United States. The **D**egree-**D**ays, **R**isk, and **P**henological event mapping (DDRP) platform serves as an open-source and decision support tool that can predict the potential distribution, number of generations, life stages present, and dates of phenological events of a target species. DDRP is written entirely in R, makin capitalizes on multiple R packages to generate gridded and graphical outputs. Currently we are using DDRP to model 15 high-priority invasive insect species (see below), but its process-based mod broad spectrum of organisms with temperature-dependent development. The DDRP platform will enhance efforts to prevent, monitor, and manage new and emerging invasive pests in the United St

Full paper available 12/31/2020 at: Barker et al. (2020) **Open source code at:** https://github.com/bbarker505/ddrp_v2 **Guide for** users including platform requirements (updated 10/28/2020)

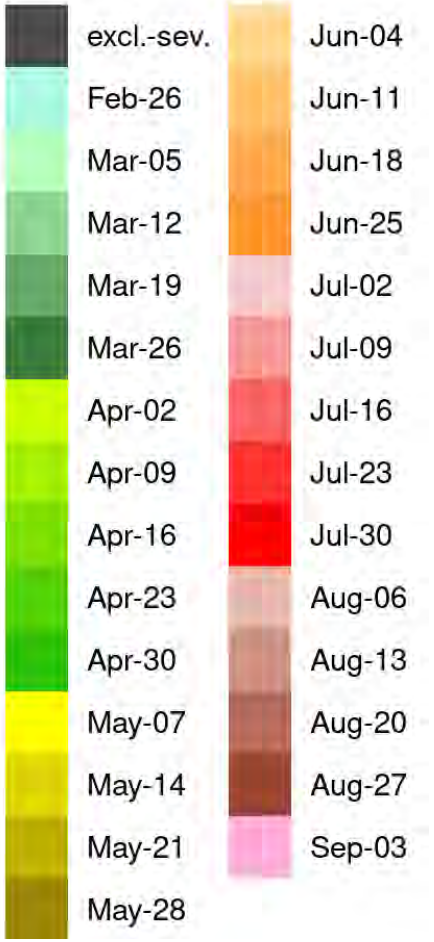
Species directory link documentation	First spring adults	First egg hatch	Current stages and generations	No. of generations per year
1. ALB **asian longhorned beetle** *Anoplophora glabripennis* model spreadsheet				
2. ASRB **asiatic rice borer** *Chilo suppressalis* model spreadsheet				
3. CGN **honeydew moth** *Cryptoblabes gnidiella* model spreadsheet white paper				
4. EAB2 **emerald ash borer** *Agrilus planipennis* model spreadsheet				
5. ECW **egyptian cottonworm** *Spodoptera littoralis*				

https://uspest.org/CAPS

Example for Old World bollworm: 2023



Date of adult emergence 2023



Old world bollworm
(*Helicoverpa armigera*)

Forecasts for last 11 years (2013-2023)

- Adult emergence varies annually by as much as 1 month
- Some areas consistently unsuitable

Old world bollwor
(Helicoverpa armige

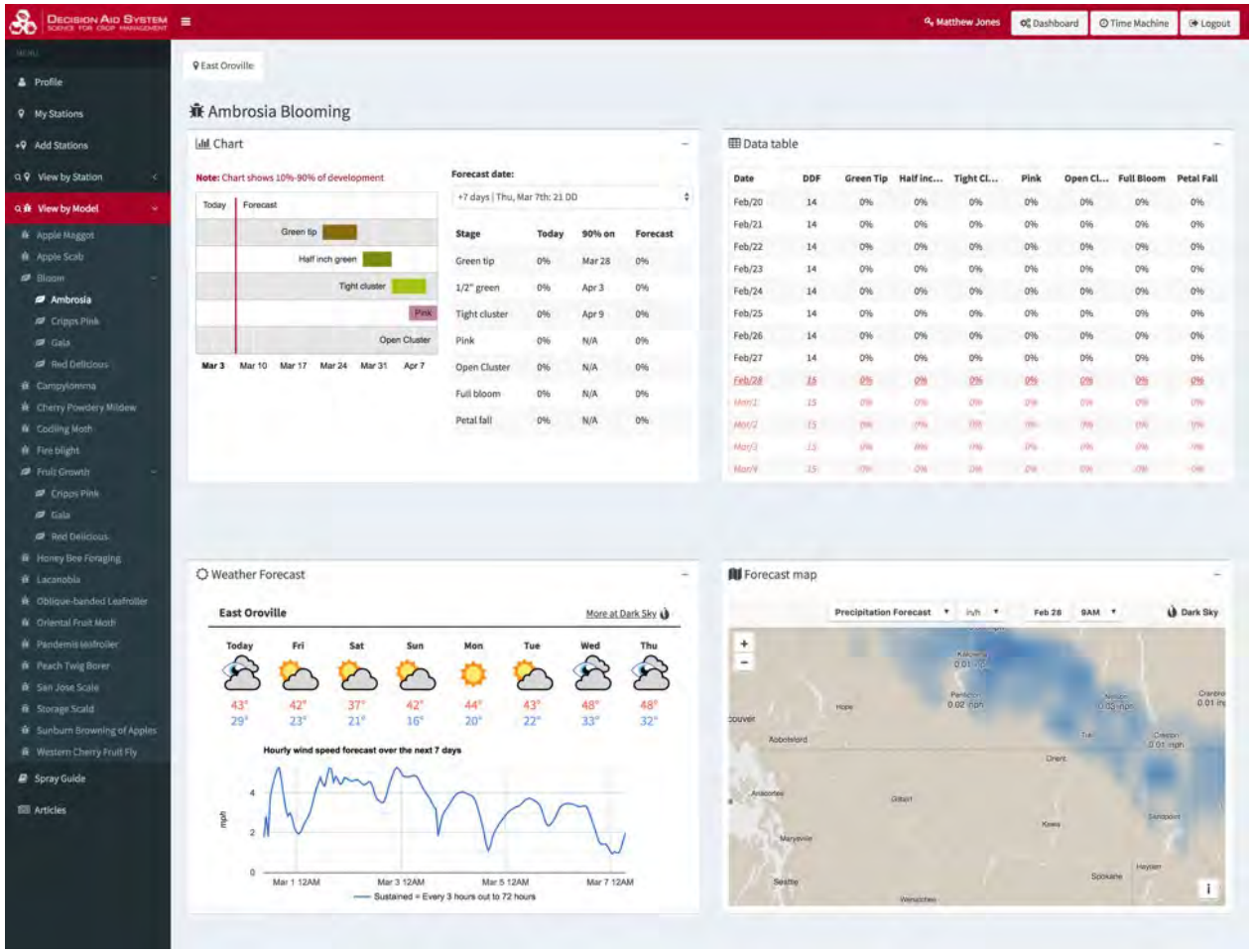
Date of adult emergence

excl.-sev.
Mar-23
Mar-30
Apr-06
Apr-18
Apr-24
Apr-27
May-04
May-12
May-18
May-25
Jun-01
Jun-08
Jun-15
Jun-22
Jun-29
Jul-06
Jul-13
Jul-20
Jul-27
Aug-03
Aug-10
Aug-17
Aug-24
Aug-31

Other decision support models

WSU Decision Aid System

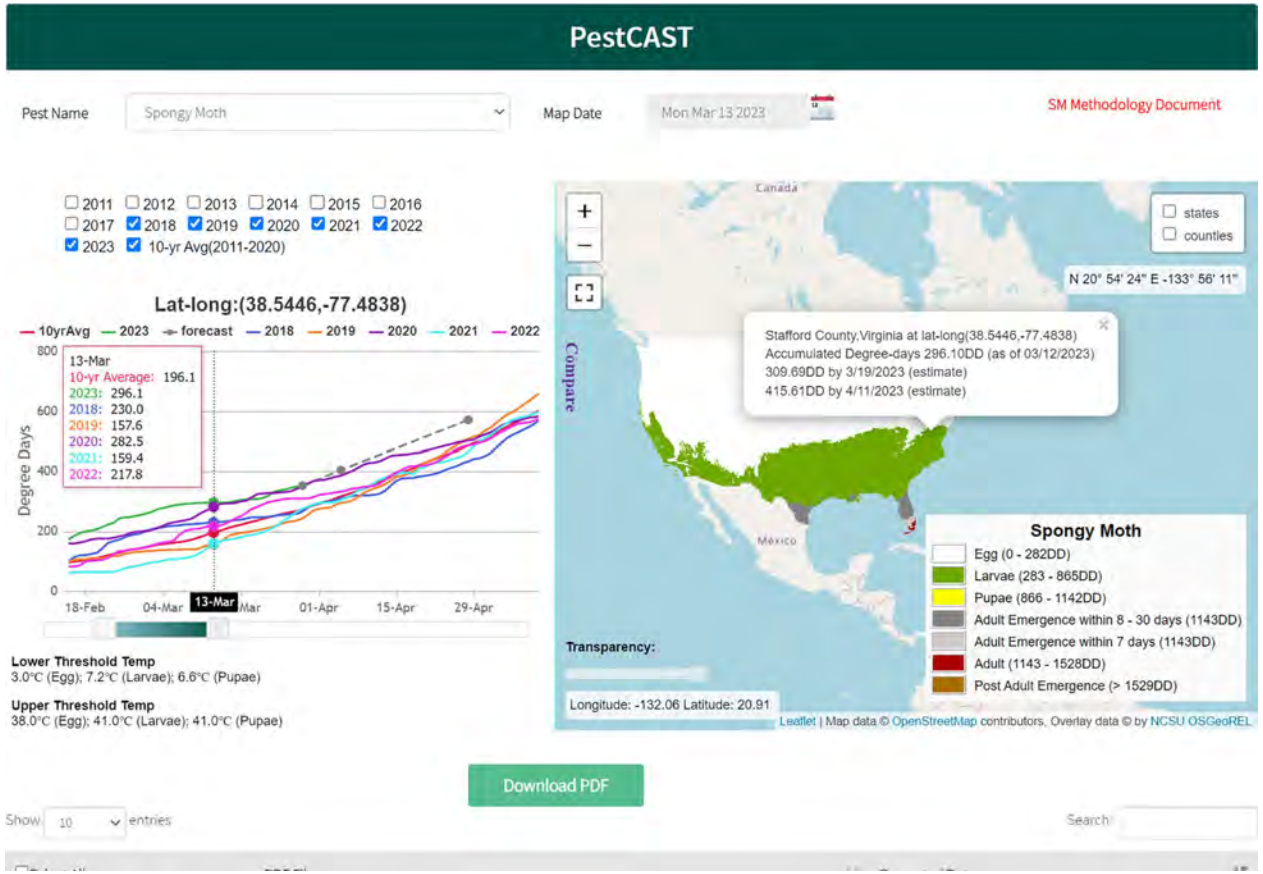
https://decisionaid.systems



https://treefruit.wsu.edu/tools-resources/wsu-das/

SAFARIS System

https://safaris.cipm.info



Takeuchi et al. (2023) *Frontiers in Insect Science*

Other decision support models

USA National Phenology Network Pheno Forecast series

https://www.usanpn.org/news/forecasts

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Future work

Develop spatial models
for new invasive species

Brown rot
Monilinia spp.

Japanese beetle
Popillia japonica

Emerald ash borer
Agrilus planipennis
(Completed 2023)

Cheatgrass
Bromus tectorum

Spotted lanternfly
Lycorma delicatula
(Nearing completion)

Photo credits: Matt Bertone, Lawrence Barringe

Collaboration w/ USA National Phenology Network

http://usanpn.org/data/forecasts/EAB

Explore phenological findings

VISUALIZATION TYPE
Map

BASE LAYER
Emerald Ash Borer Adult
March 31, 2023

BOUNDARY

YEAR
2023

SPECIES/PHENOPHASE

FEATURES
Data precision filter: 30 days

RESET VISUALIZATION
Reset visualization

SHARE VISUALIZATION
Copy link to clipboard

EXPORT VISUALIZATION DATA
Export data

Events

- Adult emergence
- Egg hatch

E-mail notifications

Future work

Develop spatial models for new invasive species

Brown rot
Monilinia spp.

Japanese beetle
Popillia japonica

Emerald ash borer
Agrilus planipennis
(Completed 2023)

Cheatgrass
Bromus tectorum

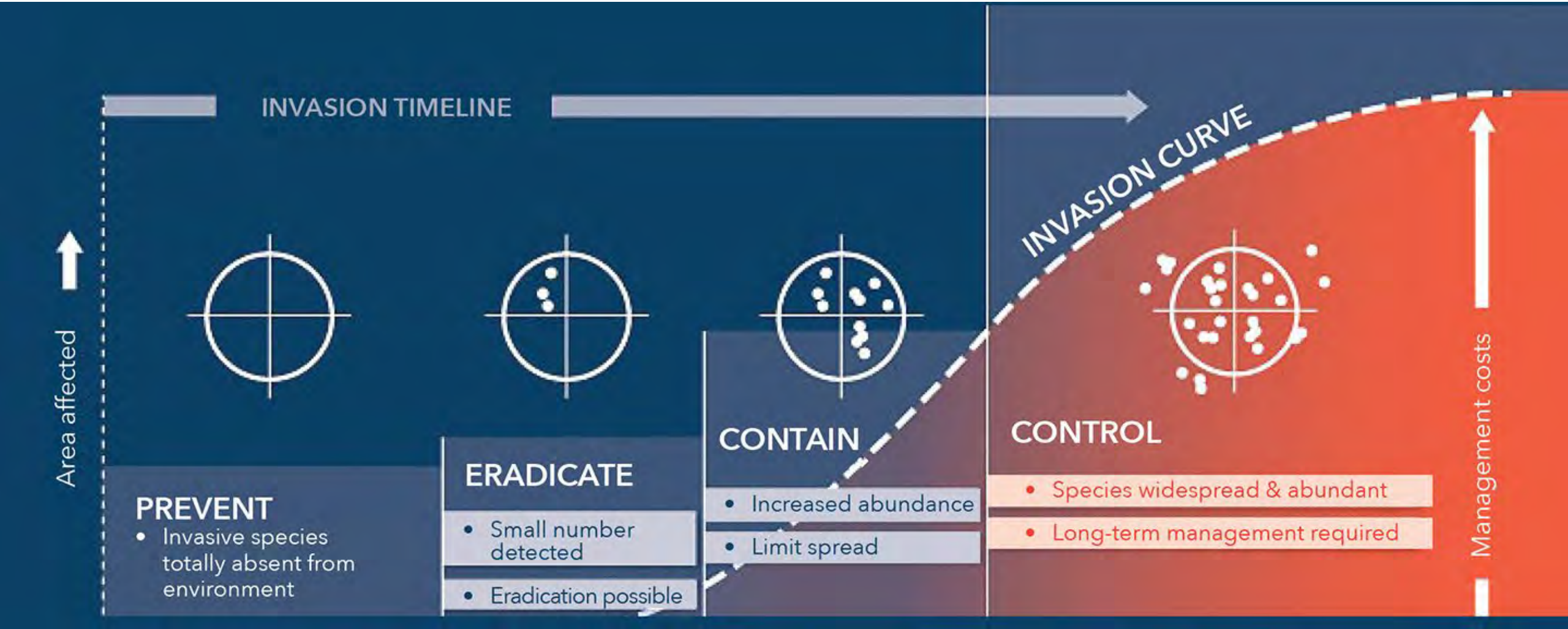
Spotted lanternfly
Lycorma delicatula
(Nearing completion)

Conduct outreach and solicit observations for model validation

nature's notebook
A project of the USA-NPN

Photo credits: Matt Bertone, Lawrence Barringer, Alamy Stock Photo

Takeaway #1: prevention and eradication are the most cost-effective and environmentally safe approaches for dealing with invasives



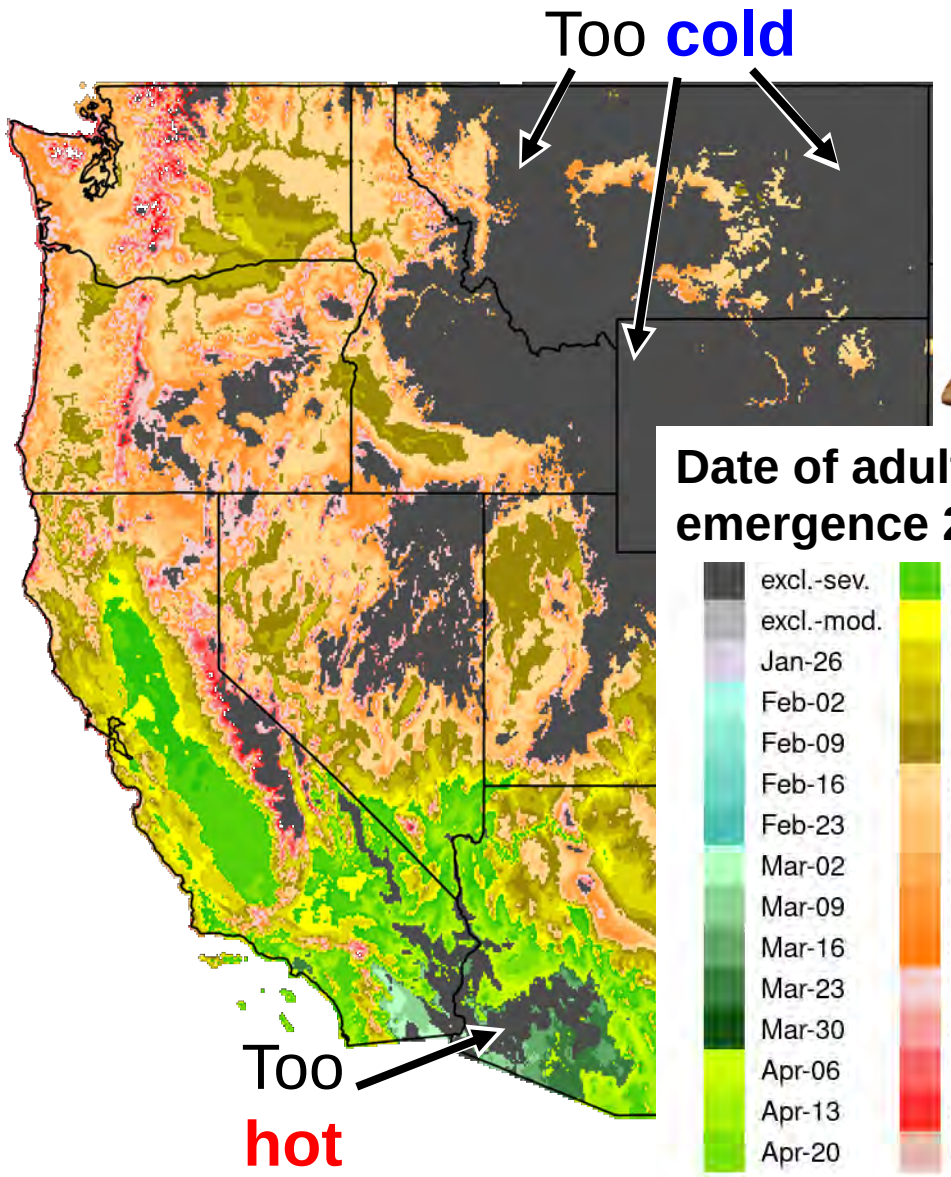
Takeaway #2: Models can help us prevent and respond to invasions

Phenology models

- Know ***when*** to expect a life stage targeted by surveillance or management

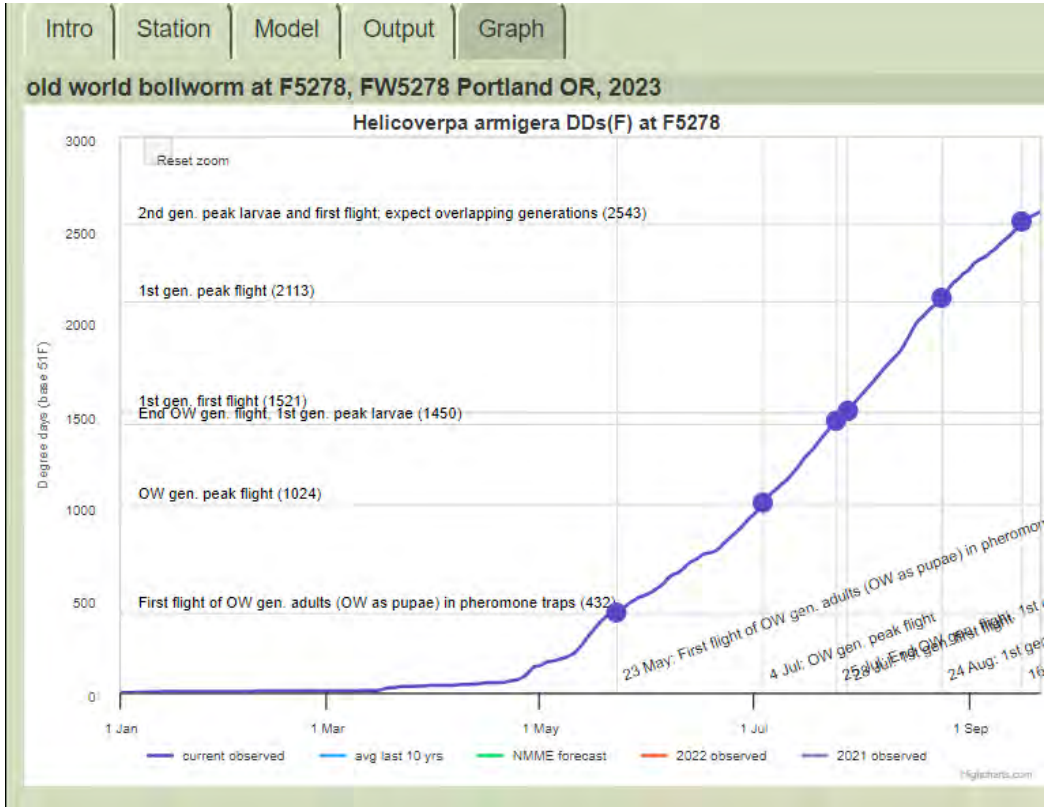
Establishment risk models

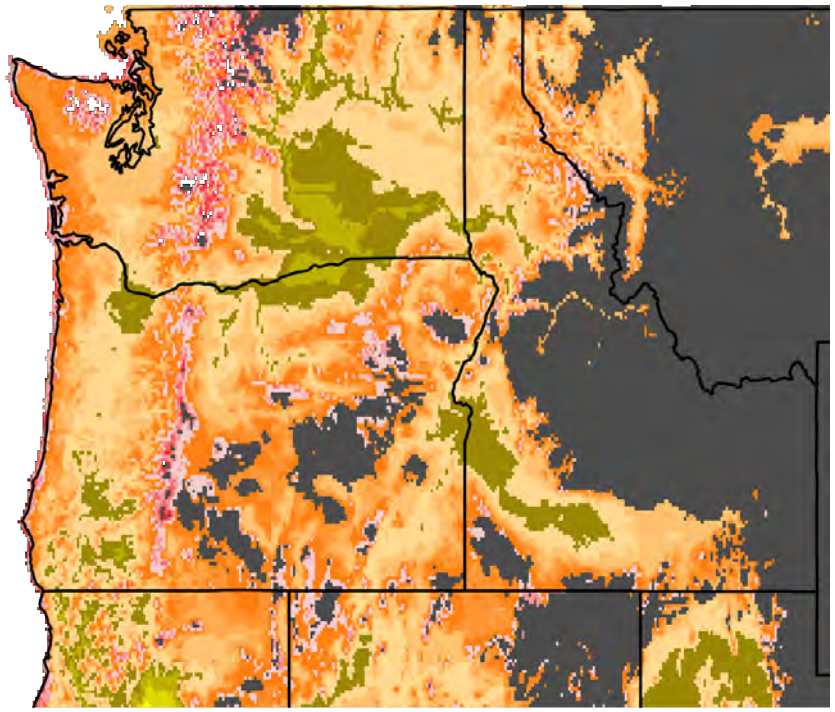
- Know ***where*** to focus search efforts

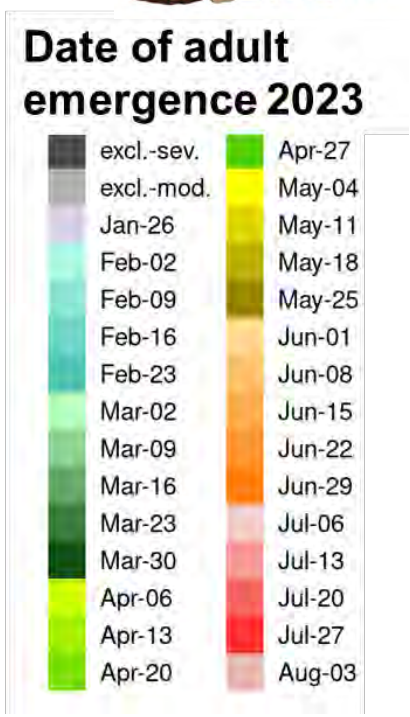


Takeaway #3: Forecasts at USPest.org

Forecasts from single-site phenology models (N=144) and spatial models (N=16) freely available







Thank you!

USPest.org

- Site-based models:
  https://uspest.org/wea
- Spatial models:
  https://uspest.org/CAPS

Other resources

- Oregon IPM Center (info hub)
  https://agsci.oregonstate.edu/oipmc
- WSU Decision Aid System
  https://decisionaid.systems
- SAFRIS system
  https://safaris.cipm.info
- USA National Phenology Network Pheno Forecasts
  https://www.usanpn.org/news/forecasts

Oregon State University
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USDA NIFA

SERDP
DOD ▪ EPA ▪ DOE

USDA Animal and Plant Health Inspection Service
PPQ
Plant Protection and Quarantine

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GET IN TOUCH