DDRP: a modeling tool to guide decision making for pest surveillance and management

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Abstract

The **D**egree-**D**ay, establishment **R**isk, and **P**henological event mapping system (DDRP) is modeling tool used to predict real-time and forecasted phenology and climate suitability of invasive species, biological control agents, and IPM pests in the conterminous U.S. (Barker et al. 2020). Model outputs can provide guidance on both ***where** and **when*** to conduct monitoring and management activities. We highlight some of our previous modeling work on 16 high-risk pest insects for the USDA APHIS PPQ Cooperative Agricultural Pest Survey program (http://uspest.org/CAPS). Our future work will extend DDRP's capacity to model a wider range of agricultural biosecurity threats including weeds and plant pathogens, build and validate models for five major agricultural pests including spotted lanternfly (*Lycorma delicatula*) and cheatgrass (*Bromus tectorum*), provide model outputs as interactive online visualizations, and solicit ground-based observations for use in forecast validation. These efforts will facilitate surveillance and management operations taking place in the ***right place*** at the ***right time***, allowing for rapid and cost-effective detections and responses to pests.

Credits

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USDA APHIS SERDP DOD • EPA • DOE

Introduction

What is DDRP?

- Open-source (written in R) modeling tool that integrates mapping of pest phenology and climate suitability
- Outputs can provide timely and comprehensive guidance on ***where*** and ***when*** to expect a pest over a growing season
- Uses a process-based (mechanistic) modeling approach (**Fig. 1**)
- Developed over several years to help the USDA APHIS PPQ Cooperative Agricultural Pest Survey (CAPS) program
- Described by Barker et al. (2020) and available at GitHub (http://github.com/bbarker505/ddrp_v2.git)
- A version that can model insects with photoperiod-cued diapause is also available (Grevstad et al. 2022)

Goals of DDRP

Provide decision support that can improve:
- pest surveillance in space and time
- timing of IPM actions to reduce pest pressure
- timing and location of biocontrol agent releases

Modeling overview

DDRP imports gridded daily climate data and a species parameter file to separately model phenology and climate suitability over a daily timestep (**Fig. 1**). The tool accepts any source of gridded climate data for any time frame. We run DDRP using daily PRISM data for real-time (current) models for the conterminous U.S. (CONUS). Forecast models use NMME data (7-mo forecasts) or recent 10-yr averages.

Species models

DDRP models have been developed for 16 invasive insects, three biocontrol insects, and one plant pathogen (**Table 1).** Regularly updated outputs for the invasive insects are available at http://uspest.org/CAPS.

Example 1: light brown apple moth

Light brown apple moth (LBAM), *Epiphyas postvittana,* is an extremely polyphagous insect and a major pest of fruits (**Fig. 2**). It is established in California and could potentially spread to other states. We developed a DDRP model using previously published data and the CLIMEX program, and validated forecasts using trapping data and presence records for LBAM in California (**Fig. 2**). As an example decision support product, we show a phenological event map which depicts dates of earliest egg-laying by the overwintered generation for 2022, integrated with predictions of the potential distribution (**Fig. 3**). The map could help better time monitoring of eggs and emergence of adults, and to focus surveillance in areas at risk of establishment, such as in the Southeast.

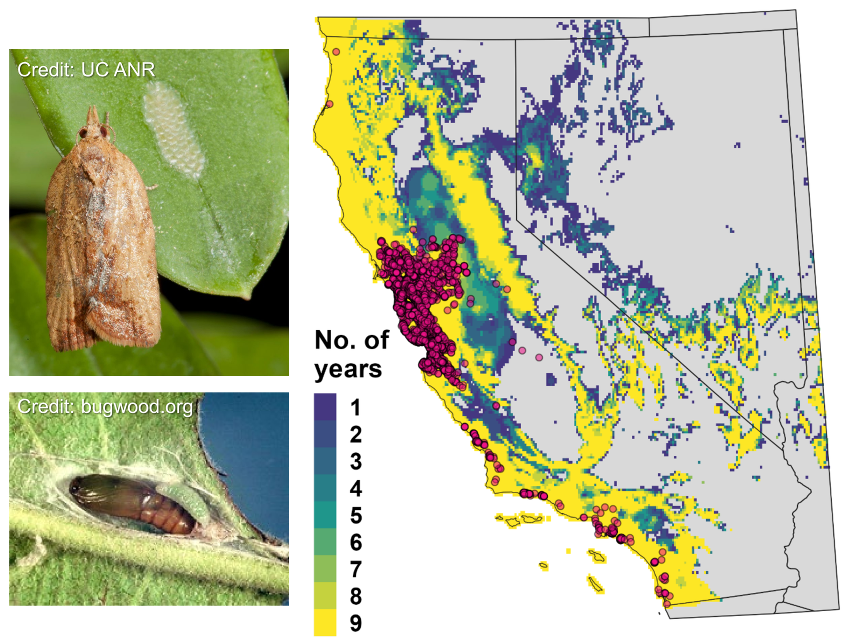


Fig. 2. DDRP included most LBAM records (97%; red circles) in the potential distribution for each of nine recent years, indicating that it can produce realistic estimates of establish-ment risk for this species.

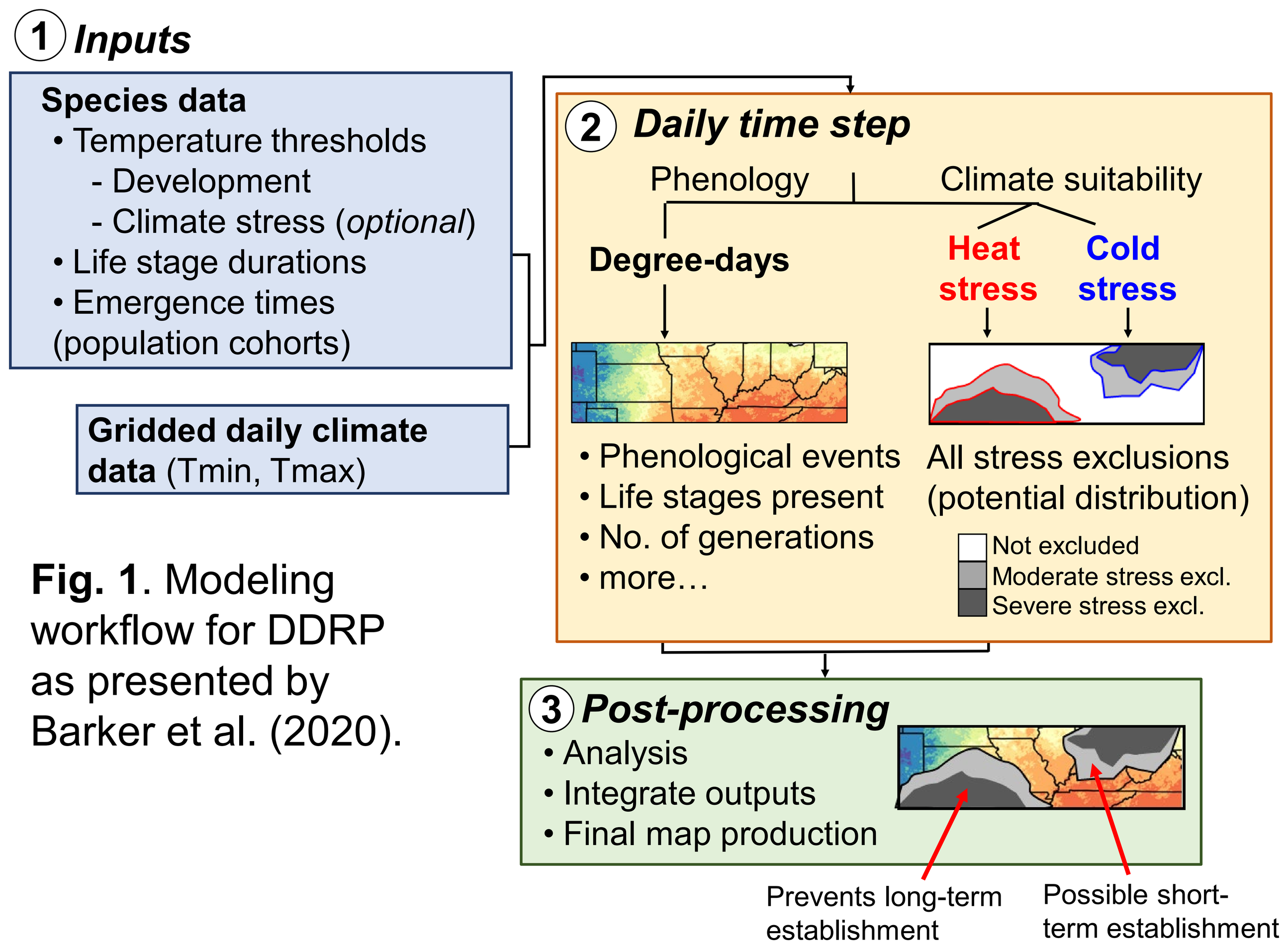


Fig. 1. Modeling workflow for DDRP as presented by Barker et al. (2020).

Table 1. DDRP models developed to date.

Invasive insect | Biocontrol insect | Invasive pathogen

Species	Common Name	Status in CONUS
Agrilus planipennis	Emerald ash borer	Present
Anoplophora glabripennis	Asian longhorned beetle	Not pres.
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.
Aphalara itadori	Japanese knotweed psyllid	Present
Galerucella calmariensis	Black-margined loosestrife beetle	Present
Diorhabda carinulata	Northern tamarisk beetle	Present
Calonectria pseudonaviculata	− (fungal pathogen, boxwood blight)	Present

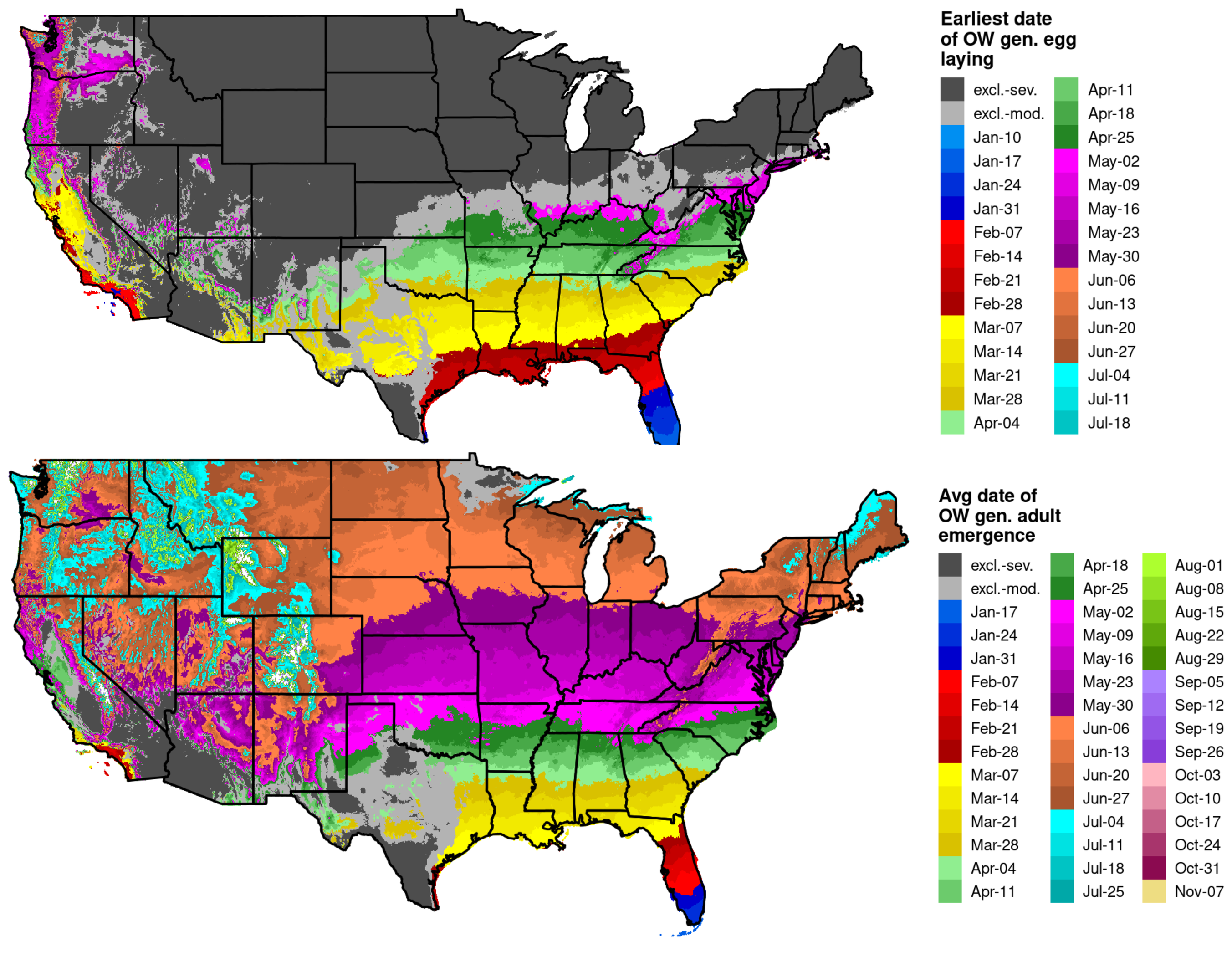


Fig. 3. Example phenological event maps for (A) light brown apple moth (*E. postvittana*) and (B) emerald ash borer (*A. planipennis*) produced by DDRP for 2022. Both maps depict the potential distrib-ution (risk of establishment) of the pests based on two levels of climate stress (excl.-sev = severe stress; excl.-mod = moderate stress).

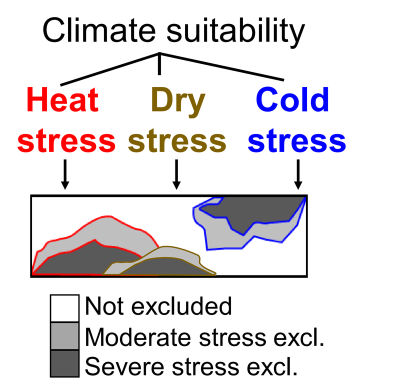
Example 2: emerald ash borer

Emerald ash borer (EAB), *Agrilus planipennis,* is an Asian beetle that has destroyed hundreds of millions of ash trees throughout North America. A DDRP model for EAB was developed using previously published data. We are in the process of validating forecasts using trapping data from U.S. populations and presence records from CONUS and Europe. A phenological event map which depicts dates of emergence of adults of the overwintered generation (**Fig. 3**) could be helpful for early detection programs because EAB is usually detected by using traps that target adults during the flight season, after they emerge. The map indicates that most of CONUS (except very hot areas) is climatically suitable for long-term establishment.

Future work

Beginning in spring 2022, we will work on a NIFA-funded project to:

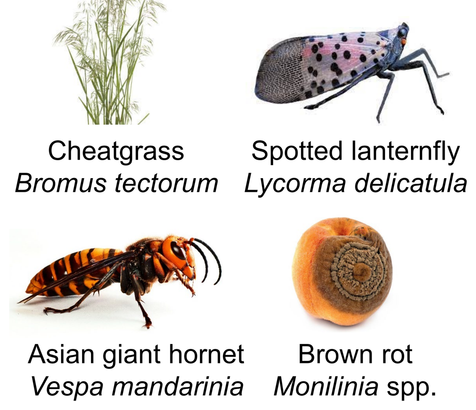
- **Add moisture factors to DDRP.** This will improve model realism for moisture-sensitive organisms (plant pathogens, weeds, etc.). A version of DDRP which models infection risk and climate suitability for boxwood blight is a starting point (see P118).



- **Build and validate DDRP models for major invasive pests** including cheatgrass and spotted lanternfly.

- **Deliver and communicate DDRP model forecasts** via USA-NPN's interactive web tools and email notifications to enable wide adoption (**Fig. 4**).

- **Engage citizen scientists in contributing observations for forecast validation** including those reported through USA-NPN's *Nature's Notebook.*



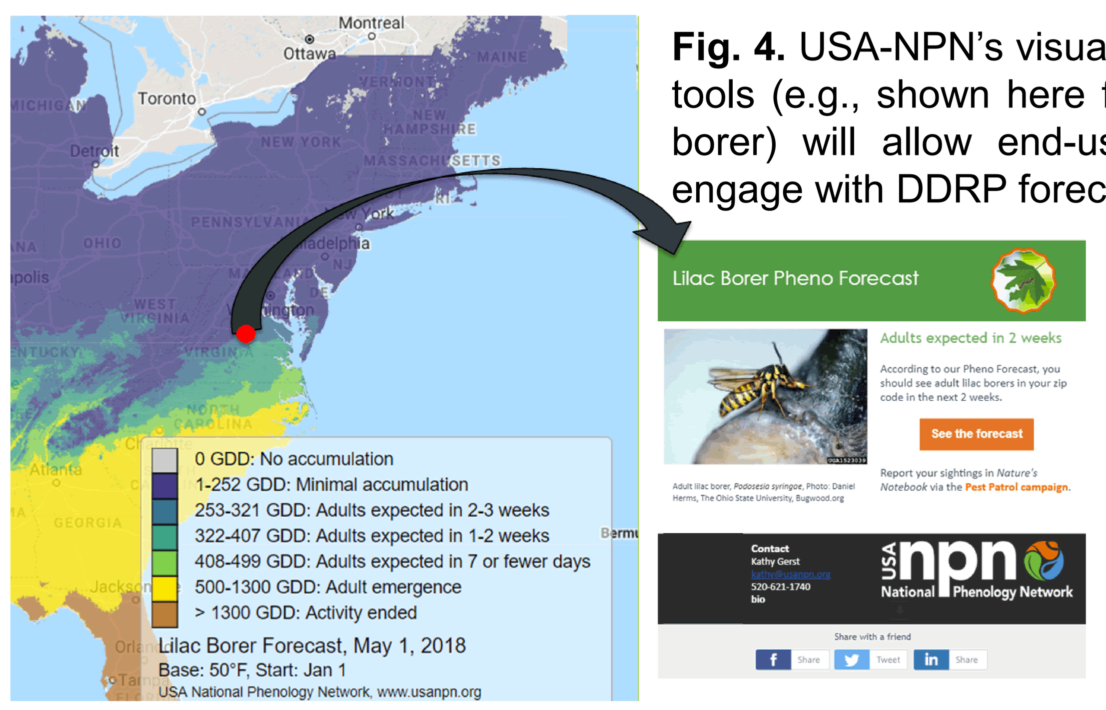


Fig. 4. USA-NPN's visualization tools (e.g., shown here for lilac borer) will allow end-users to engage with DDRP forecasts.

References

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