

# Introduction to Snake Worms and Their Management

# What are they? How many species?



How many in Vermont:  
Three out of 20 species are  
**pheretimoids**

16 pheretimoid species in  
North America

Have an annular clitellum,  
which goes all around the  
circumference of the  
worm.

Move like a snake

Occur in 37 US States

Prohibited species in  
Wisconsin and New York.

Most common species in New England

*M. hilgendorfi*



Size: 109–170 mm  
(4.29 –6.69 inch)

*A. agrestis*



Size 70–160 mm  
(2.76 - 6.3 inch)

*A. tokioensis*



Size 30–125 mm  
(1.18-4.92 inch)



# When were they first reported in some states?

- ▶ California - 4 species 1860s to 1950s
- ▶ Connecticut – 5 species 1950s
- ▶ Delaware – 3 species 2014
- ▶ DC – 1 species 1937
- ▶ Florida – 13 species 1950 – 2010s
- ▶ Georgia -12 species 1936 – 1969
- ▶ Illinois – 5 species 1914 – 2014
- ▶ Maine – 7 species 1954
- ▶ New York – 6 species 1940 - 1999
- ▶ Vermont – 3 species 2011 - 2012

Collation of first reports by Reynolds, 2018

# Place of Origin

## 分布

北海道から本州、四国、九州にかけて広く分布する。隠岐、対馬でも記録されている。

多くの地域で高頻度出現種に挙げられる (石塚, 2001; 上平, 2001a, b, 2002a, b, 2003a-c, 2004a, b, 2006, 2007, 2008, 2010, 2011, 2012, 2015b; 南谷ら, 2010a, b, 2013, 2015)。

栃木県内では分布が局部的で散在するとされていたが<sup>8</sup> (加藤, 1972)、南谷らによる調査では最も出現頻度が高い種であり、広範囲に分布していた (南谷ら, 未発表)。

国外では韓国 (Song & Paik, 1971, 1973; Hong & James, 2009)、アメリカ合衆国 (Davies, 1954; Gates, 1963, 1966, 1982; Reynolds, 1978a, 2010c, 2011a, 2015a, b) に分布する。

原産地は日本だと推定されている (Reynolds, 1978a)。



図：これまでに出版された文献に基づく、フキソクミズの分布確認地点

# How did they get here?

- ▶ Probably with horticultural trade or people collecting plant materials
- ▶ Anecdote has it that they came with DC Cherry Blossoms

Japan gave 3,020 cherry blossom trees as a gift to the United States in 1912 to celebrate the nations' then-growing friendship, replacing an earlier gift of 2,000 trees which had to be destroyed due to disease in 1910. These trees were planted in Sakura Park in Manhattan and line the shore of the Tidal Basin and the roadway in East Potomac Park in Washington, D.C.

From Wikipedia



Image: National Park Service



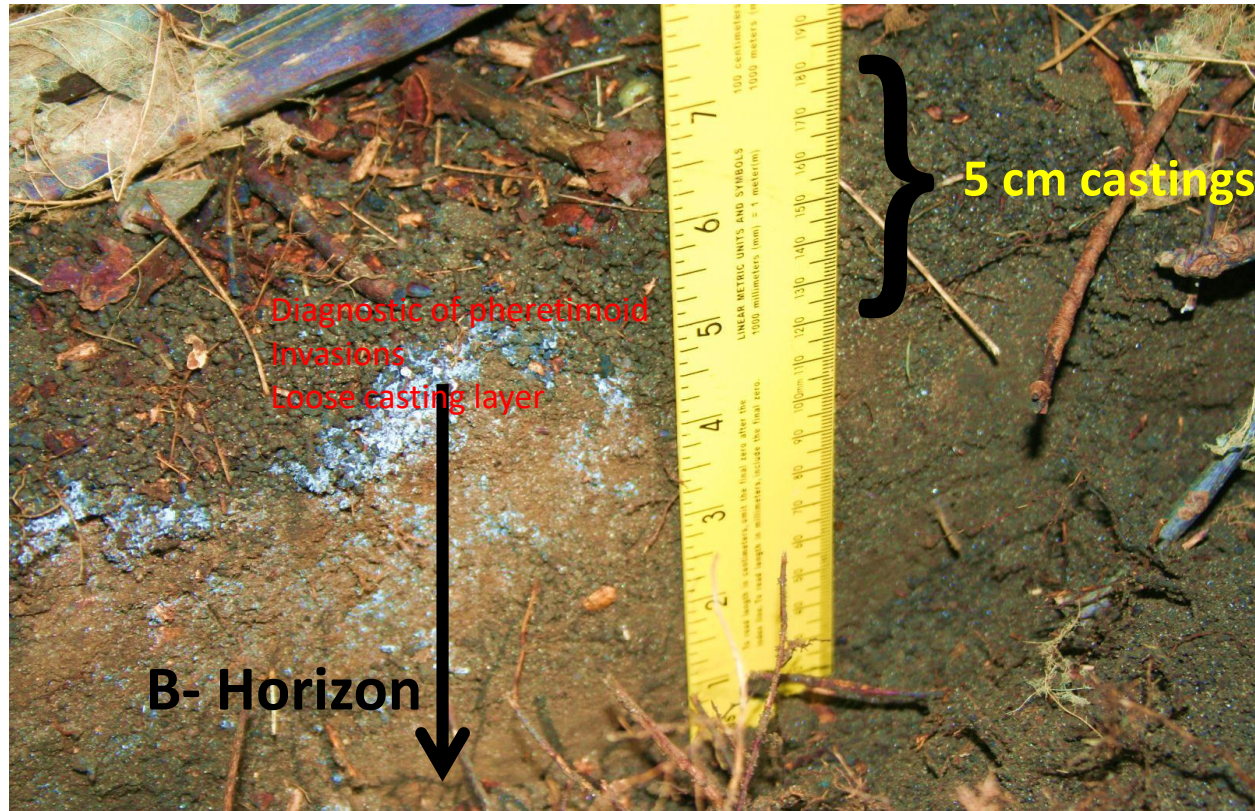
Why do we worry?



Image source: <http://clipart-library.com>



# Forest Soil Modifications by *A. agrestis*





# Forest Ecology



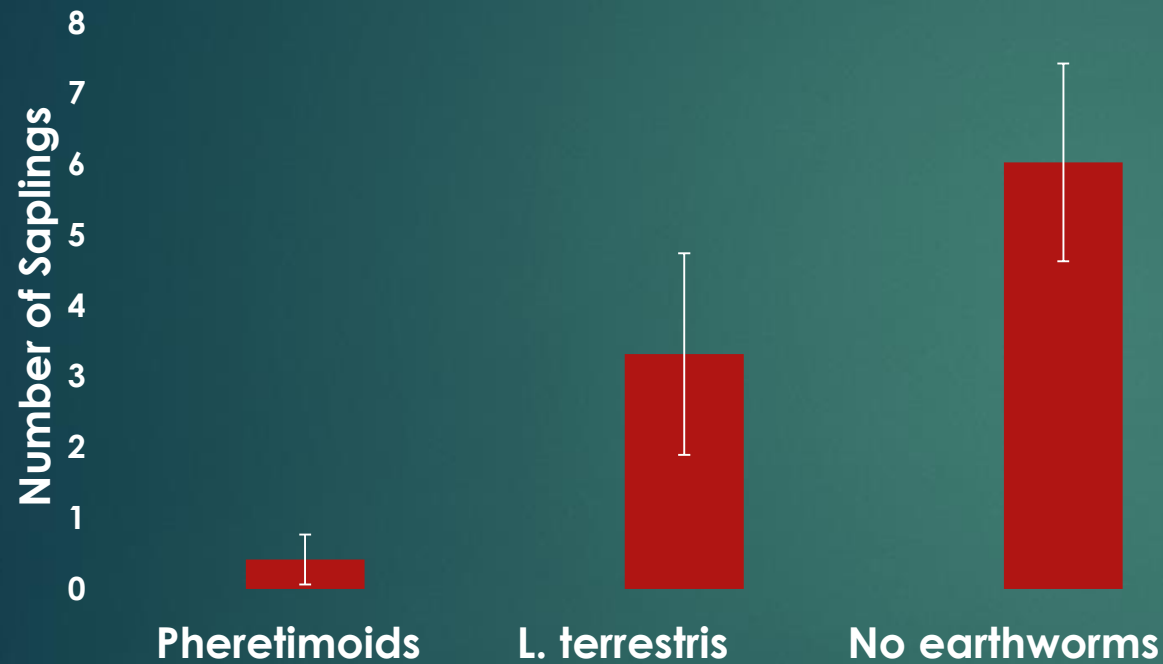
No Earthworms



Snake Worms

# Regeneration of Sugar and Red Maple

## Number of Saplings (unpublished data)



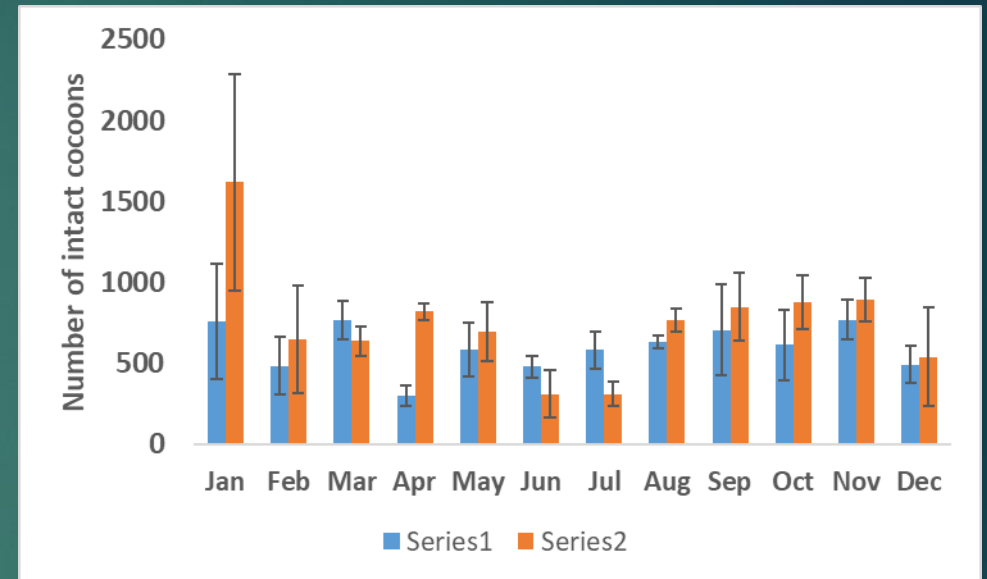
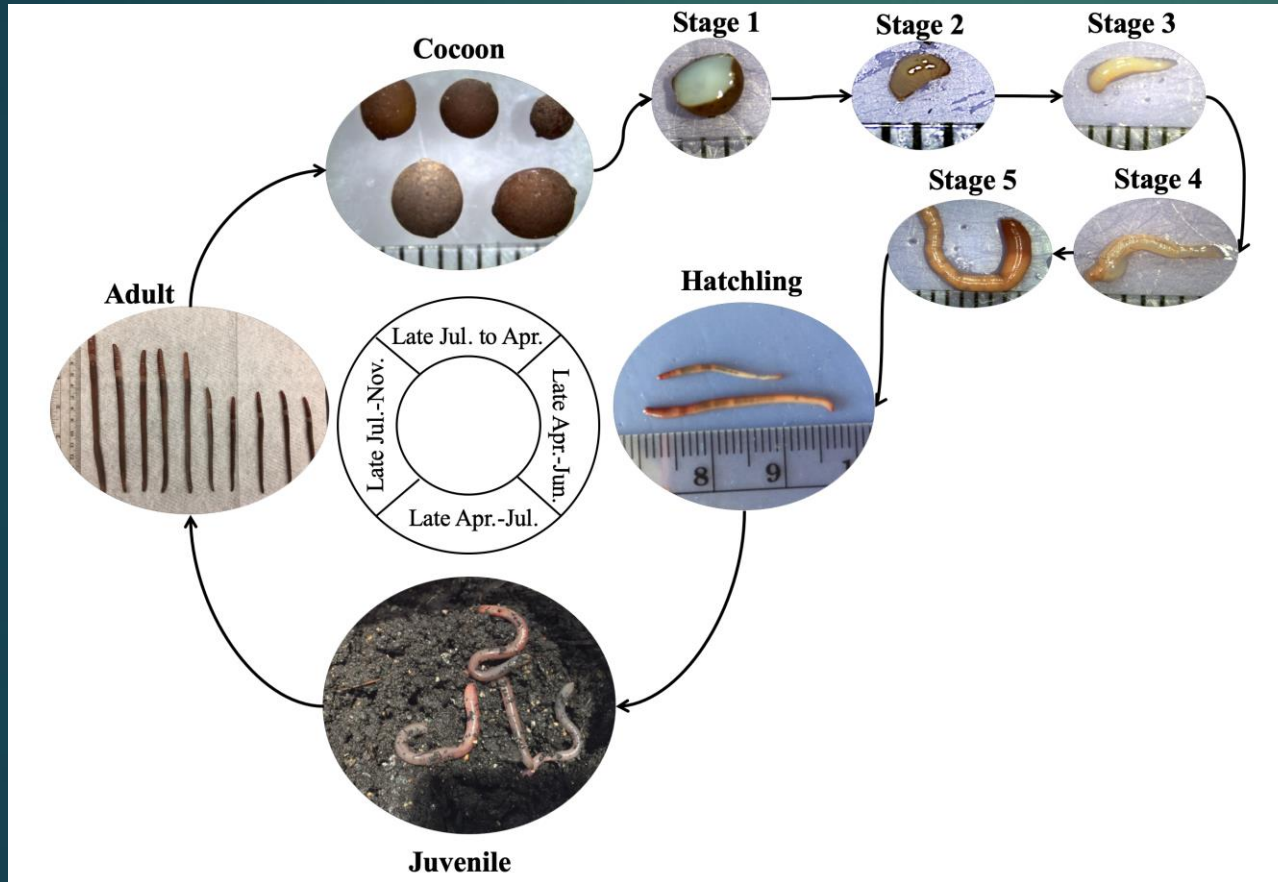
Is there hope for maple syrup?





2. What is their life cycle?

# Life Cycle

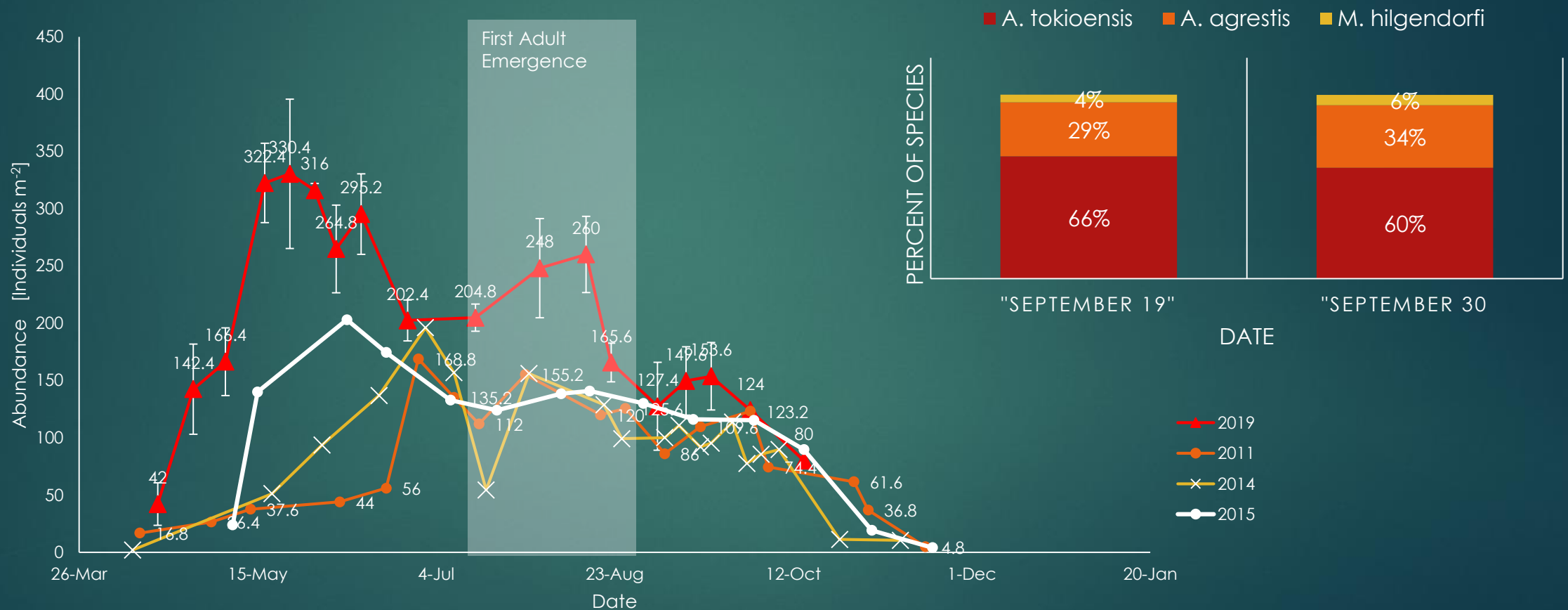


Cocoons are present year round:  
Cocoon bank? Seem to stay viable for at least two-years. Trouble for managing the worms...

Image credit: Maryam Nouri-Aiin



# Phenology of Pheretimid Worms in a South Burlington Woodland



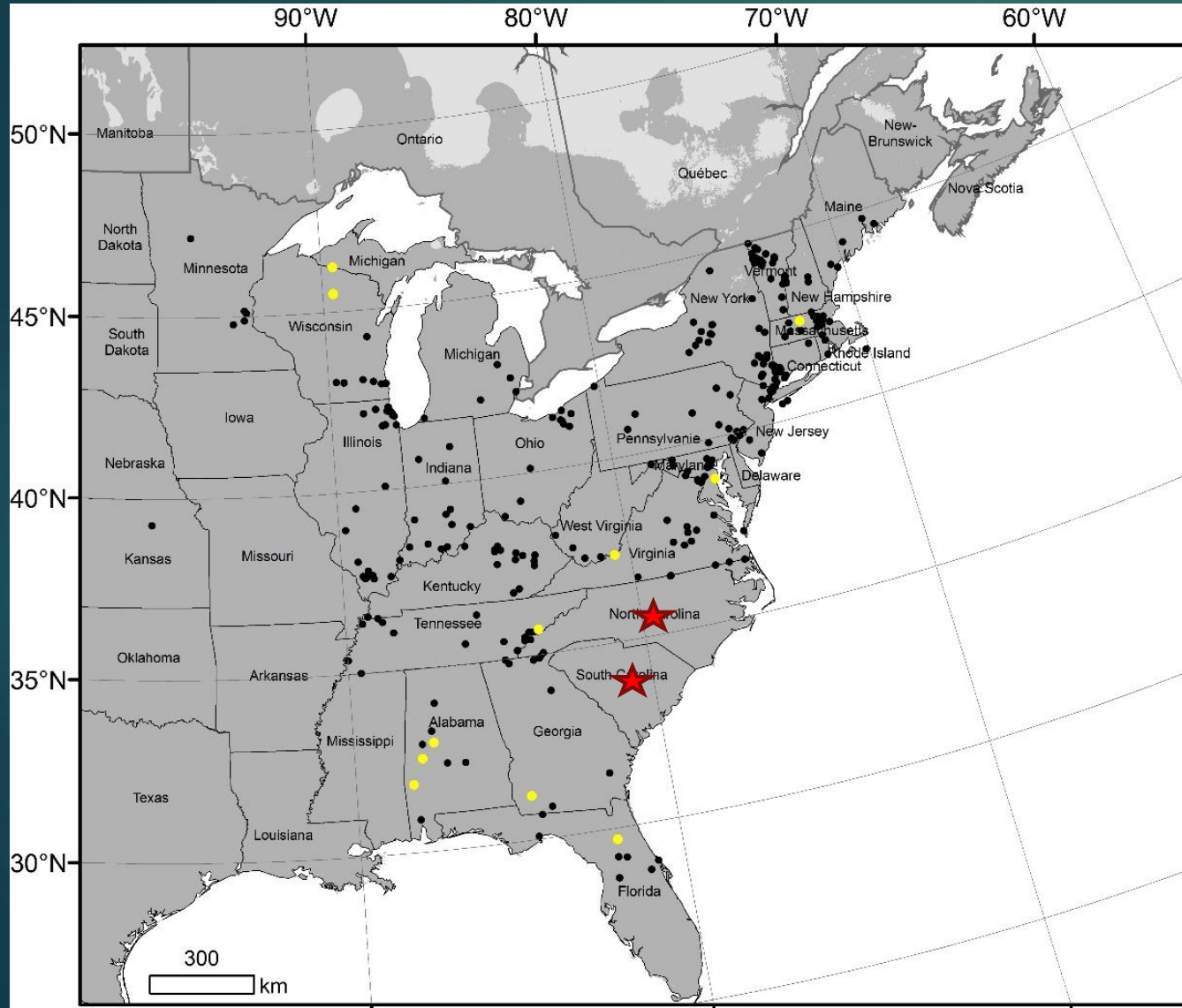




**Invasive Jumping Worms: Cocoons,  
Climate Change and Expansion at  
the Northern Limit of their Range**



# What is the distribution in eastern North America?



- Most south of 45<sup>th</sup> parallel.
- One further north in Minnesota
- One collection in Southern Ontario (south of 45° N)
- Carolinas data not yet digitized or only available on county basis
- Many more data for other states in Reynolds' check list publications (*Megadrilogica*)
- Ignore yellow markers, not always jumping worm site

Image source: Jean-David Moore, Quebec direction de la recherche forestière

# Typical Phenology

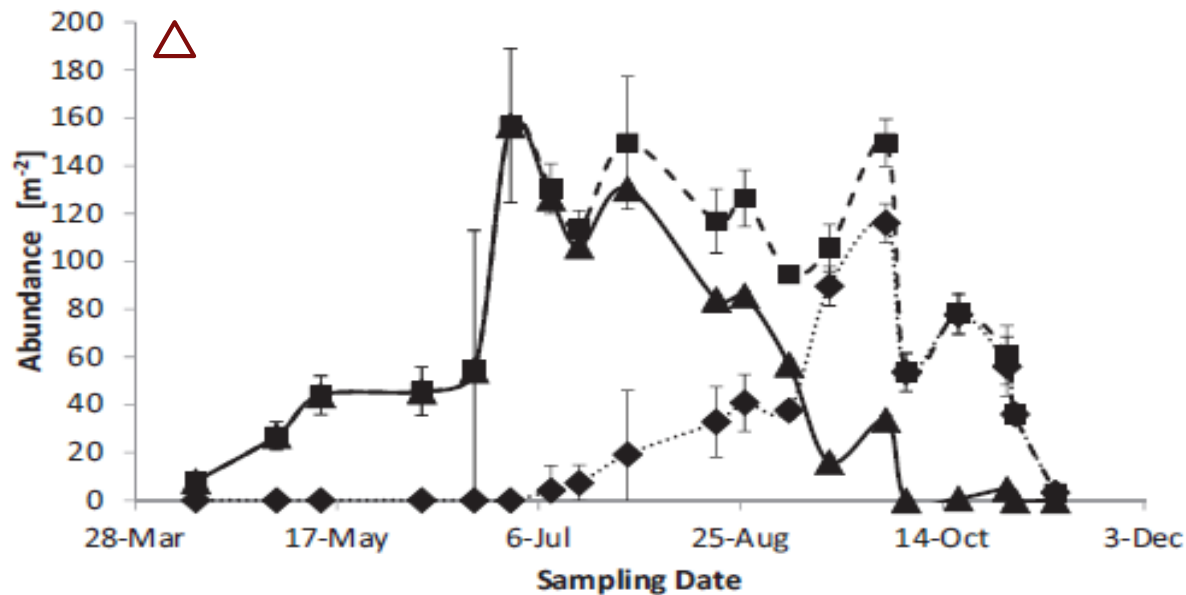


Fig. 2. Average juvenile (triangular symbols, solid line), adult (diamond markers and stippled line) and total (square symbols and broken line) abundance of *Amyntas* at the Horticultural Research Center in South Burlington, Vermont, USA for the sampling period. Error bars represent 1 standard error. First hatchling was observed April 12, 2011, the first adult on July 9. Large increases in juveniles occurred mid-June to end of June. On October 10 all individuals were adults. Large reductions in abundance occurred end of October.

1. First Hatchlings observed April 12
2. Maximum abundance June 20
3. First adult observed July 9 (88 days)
4. Other years as late as August 10 (120 days)
5. All adults in October
6. Hatching into November
7. Decrease in abundance in early July  
droughty conditions/lack of resources?
7. Crash in populations end of September, first frosts
8. Some recovery in October and final crash in November

# Life history parameters

- ▶ Several studies looked at temperature tolerances
  - ▶ Temperature tolerances:  $> 5^{\circ}\text{C}$  but  $< 35^{\circ}\text{C}$  (Richardson et al., 2009)
  - ▶ Hatchlings emerge at temperatures  $> 10^{\circ}\text{C}$  (Blackmon 2009)
  - ▶ But upper limit depends on soil moisture
  - ▶ Minimum of 90 days to maturity
  - ▶ Some fuzziness as to where the actual mortality thresholds are

Table 1. Mean percent survival ( $\pm$  standard error,  $n = 3$ ) of *Amyntas agrestis* individuals after 28 days of incubation.

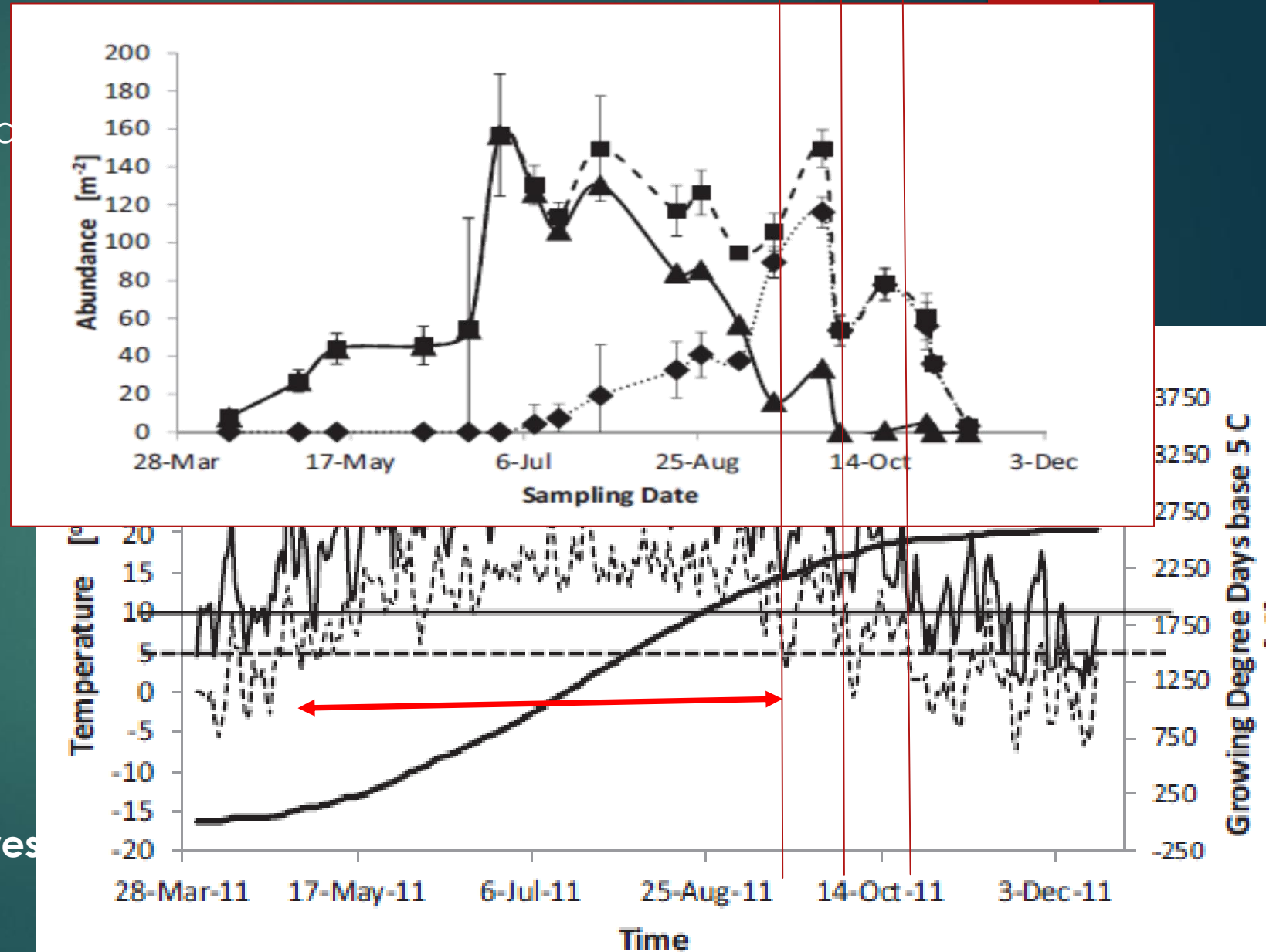
Moisture	Temperature				
	-5 °C	5 °C	12 °C	25 °C	35 °C
Low (8%)	0	0	43.8 $\pm$ 22.9	0	0
Medium (24%)	0	0	79.4 $\pm$ 6.6	24.0 $\pm$ 24.0	0
High (57%)	0	0	69.3 $\pm$ 3.5	51.1 $\pm$ 27.8	0



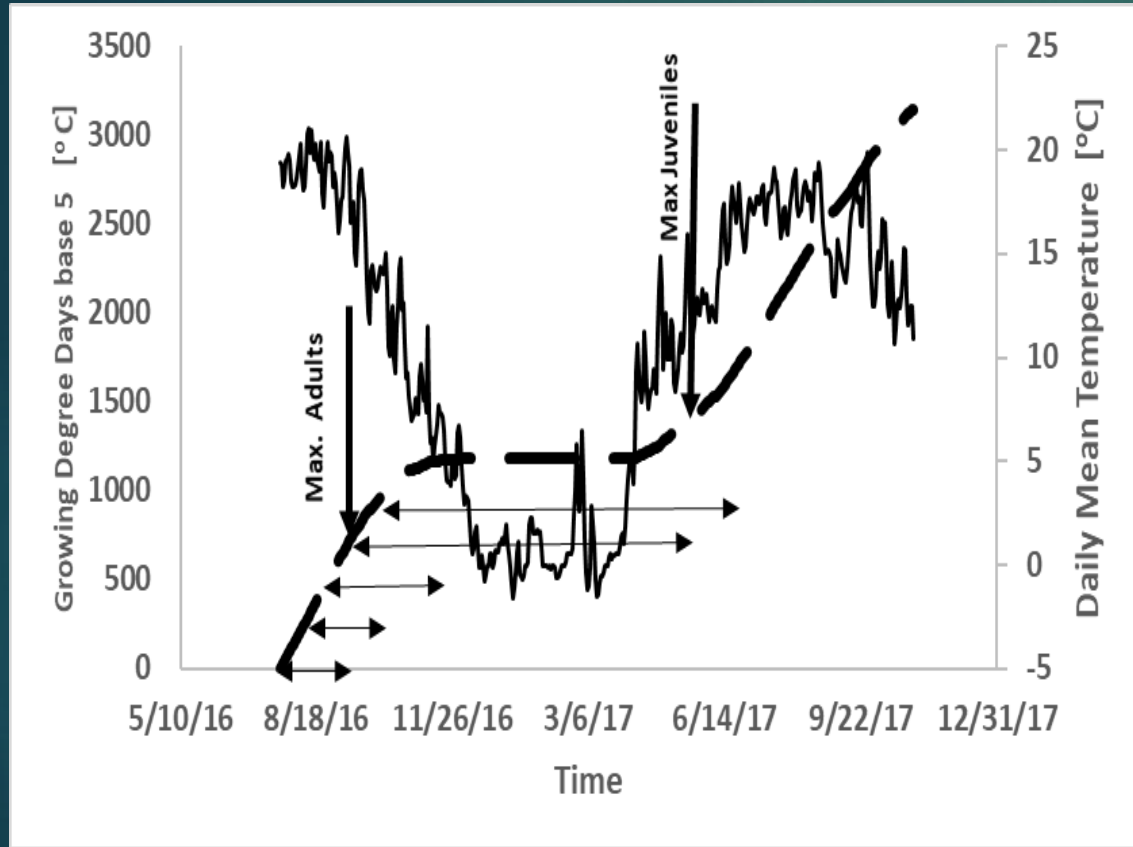
# Compare to Field Observations, South Burlington, VT

Sugar Bush, on a Windsor loamy soil  
Excessively well drained.

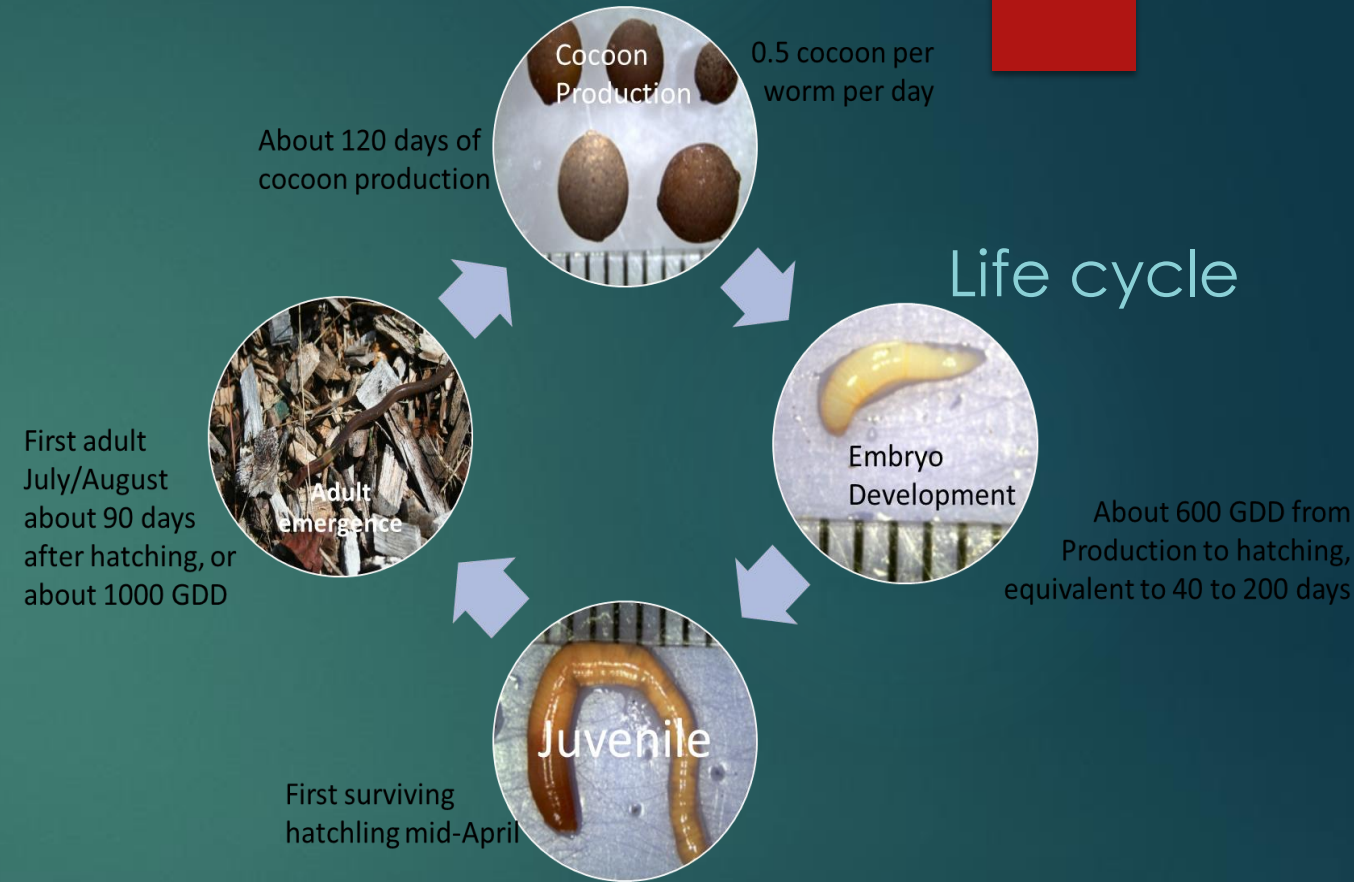
- 5°C not necessarily the mortality threshold.
- Crashes in autumn due to resource limitation? Adults tend to be a lot smaller then
- Are the worms on a timer? Just last only 8 months/GDD?
- Seem to survive at lower temperatures for at least some time.



# Typical temperature variation and embryo development



Arrows represent 600 Degree Days, likely degree days needed for embryo development

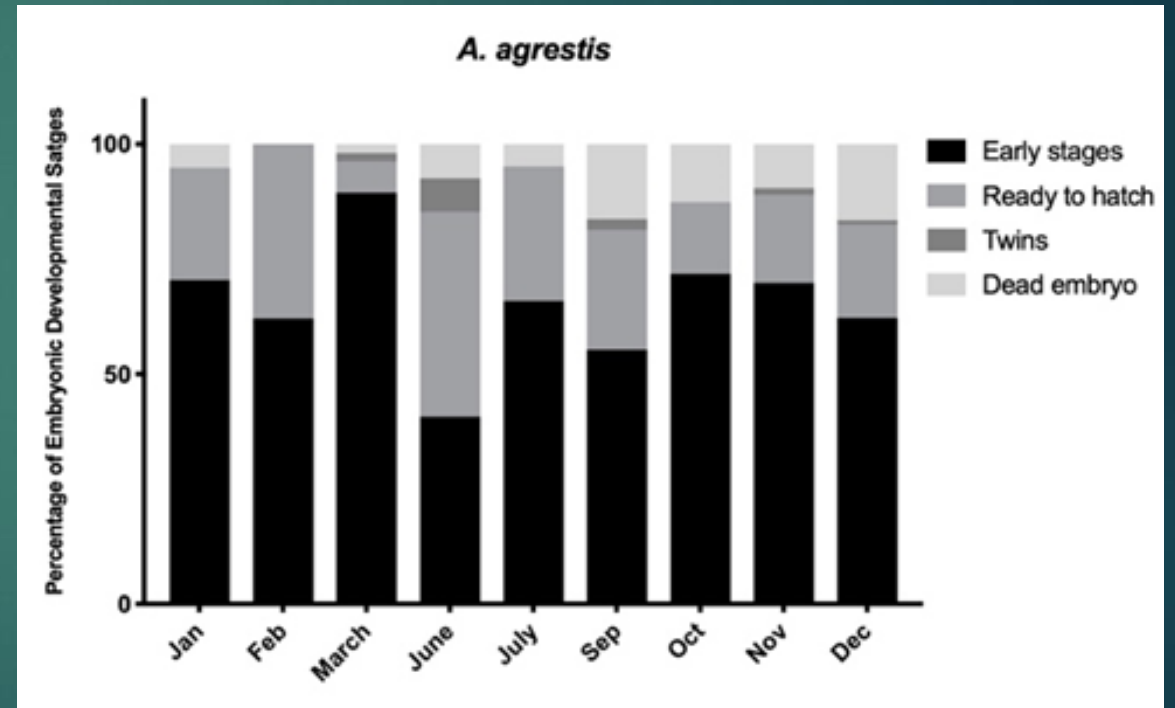
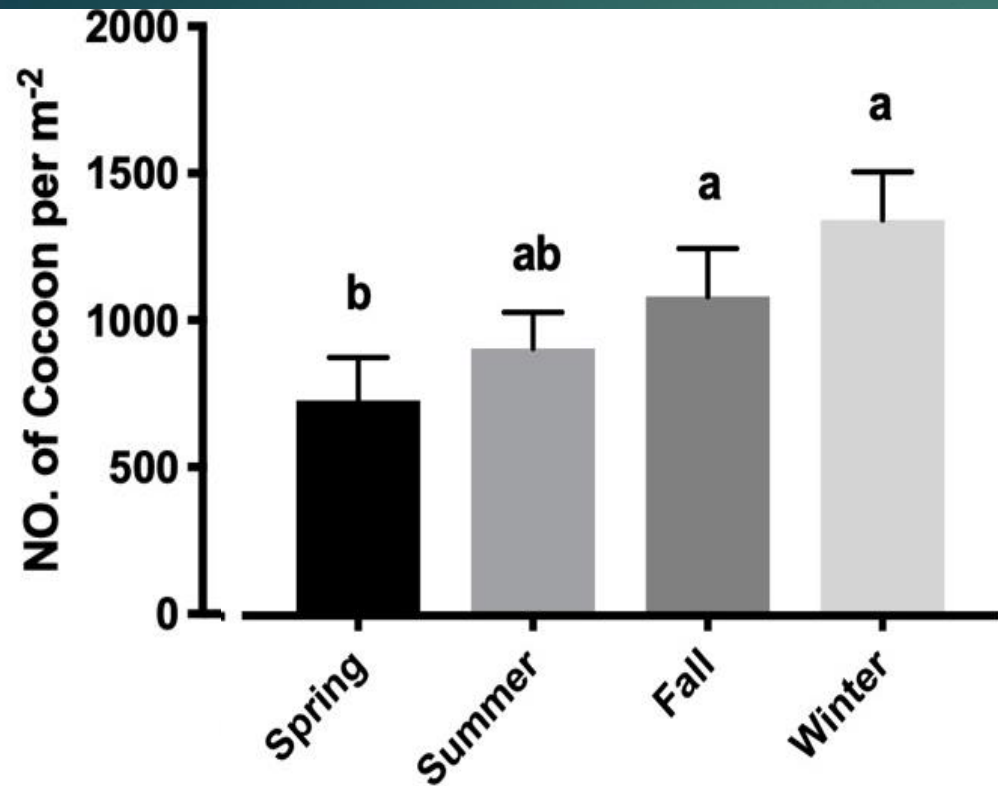


Embryo development GDD calculated from Blackmon et al., 2019, Southeastern Naturalist, in production.

# Cocoon presence and embryo development

*Amyntas agrestis* cocoons

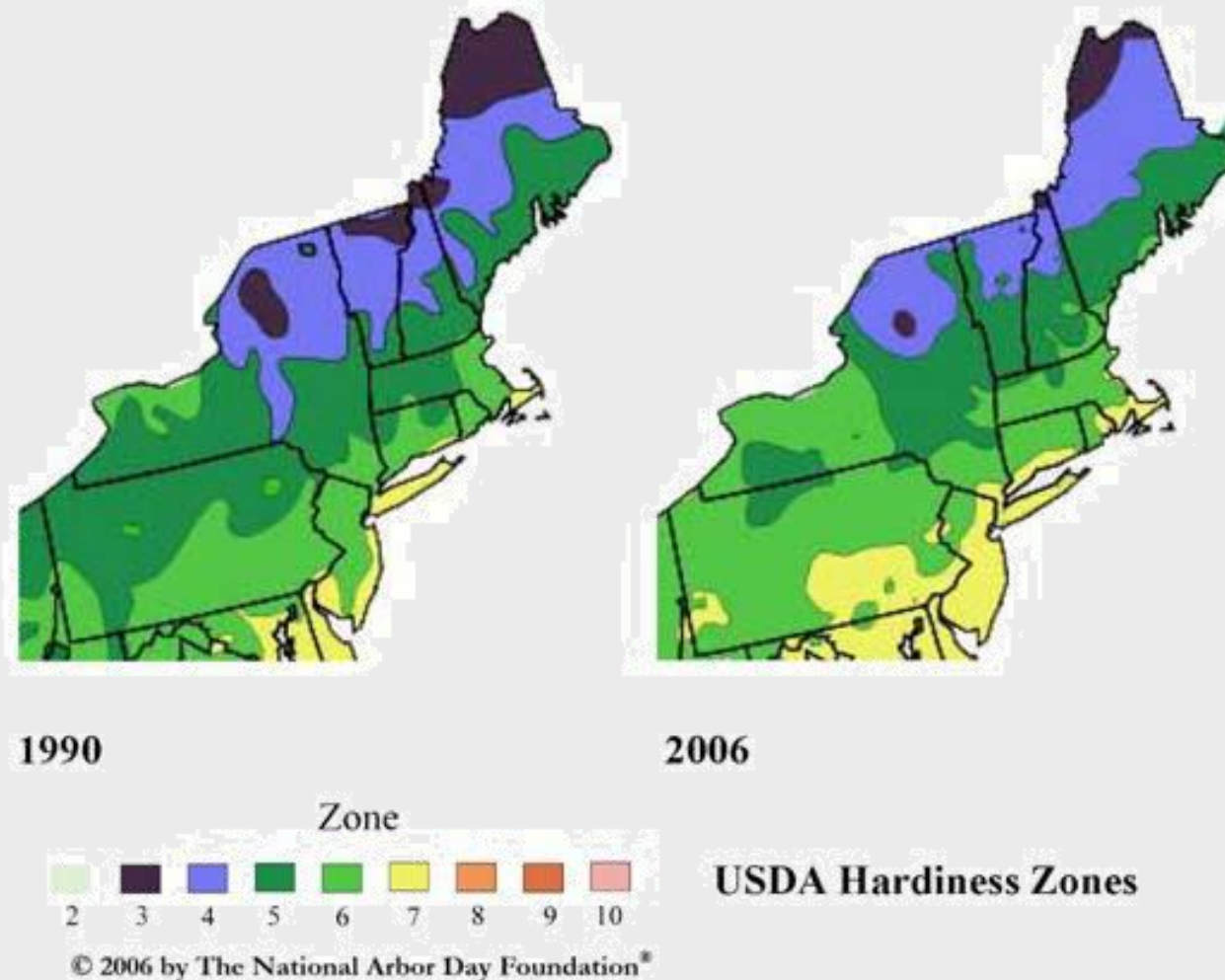
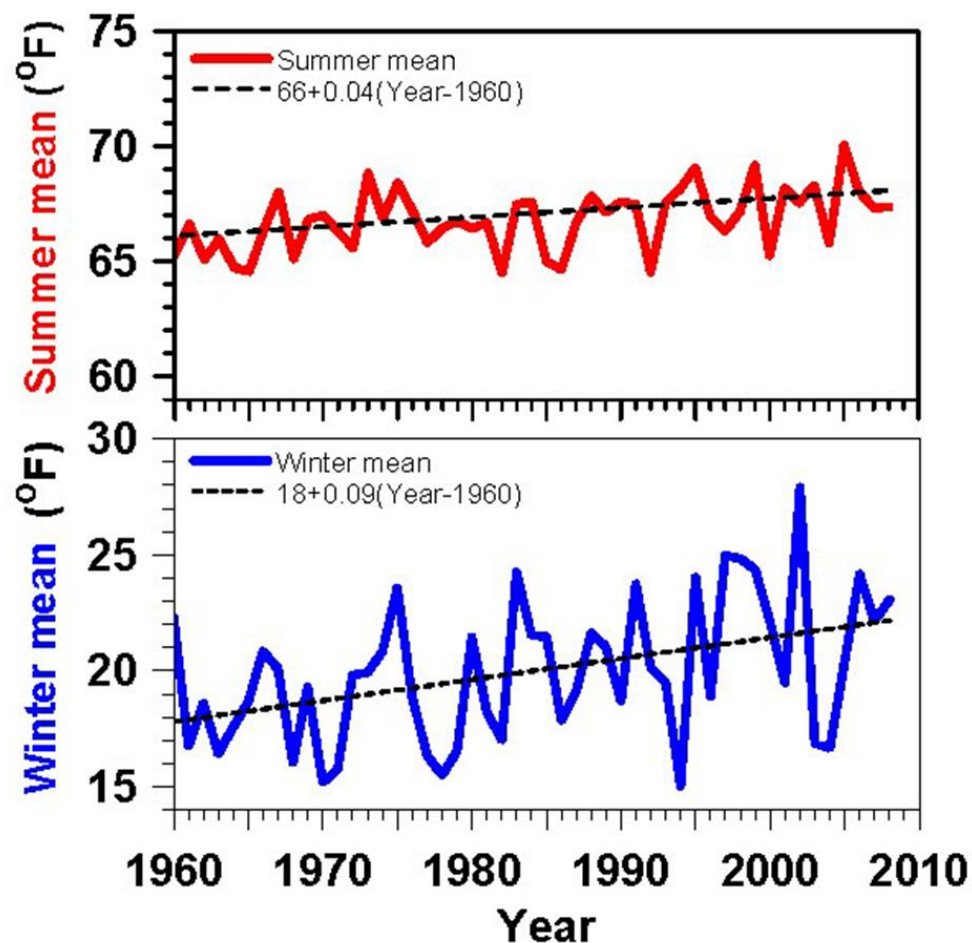
Embryo developmental stages



Source: Nouri-Aiin&Görres. 2019.

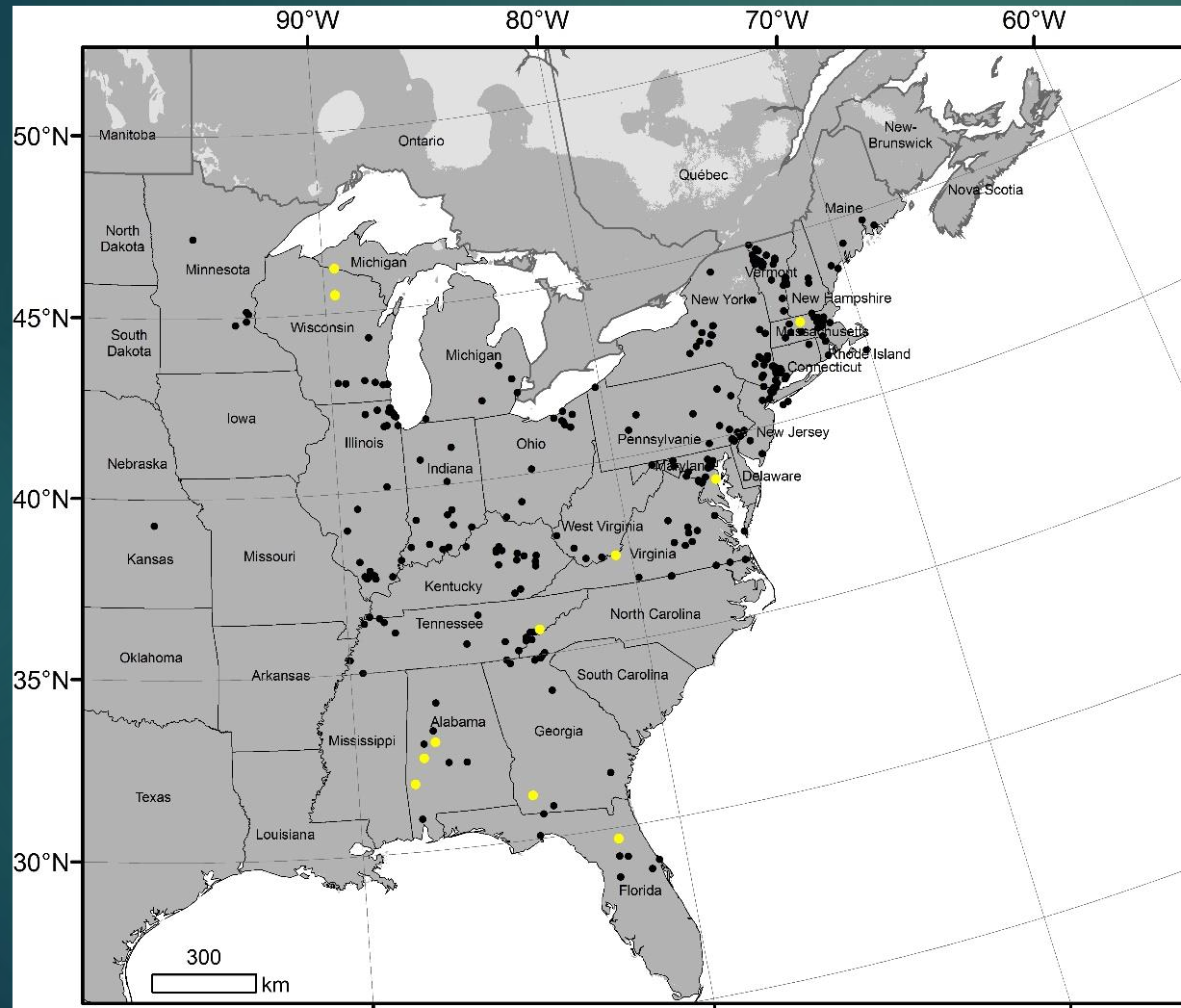


# Changes in climate have already been observed



<https://www.climatehubs.oce.usda.gov/hubs/northeast/project/adapting-climate-change-new-england-farmers>

# Extent of the invasion in the eastern USA and Canada



Potential geographic range, based on >90 days frost free

Unlikely range



confirmed phoretic mites



Potential study sites

Map by Jean- David Moore,  
Direction de la recherche forestière  
Ministère des Forêts, de la Faune et des  
Parcs

How do they move around?



# History of Earthworm Invasions in N. America

No native earthworms

Extent of last glaciation (18,000 years ago)

Native earthworms



Great Lakes Worm Watch



<https://collections.slsa.sa.gov.au/resource/PRG+1373/19/50>

First wave of invasions:  
European worms  
Lumbricidae: e.g. night crawler,  
Red worm

Second wave: Megascolecidae:  
Snake worms...

Ms. Y. has a large vegetable garden in East Calais. Last year she purchased about 20 bags of "xxxxxx-compost" and spread them on the garden. She didn't notice worms at the time. This year, her garden is full of large, aggressive worms that she believes are *Amyntas agrestis* from what she's read on-line. She notes that they are very aggressive and seem to be very intelligent, too....and that they have the telltale "flick of the tail" feature. I asked if the light band completely circles the body and she wasn't sure since she seems to have such an abundance of worms in different stages of life. Most disconcerting: Ms. Y opened an intact bag of xxxxxx-compost left over from last year and found one of the large worms in it.

E-mail from UVM plant clinic about the trials and tribulations of Ms. Y.



<https://www.fs.usda.gov/detailfull/r4/fire-aviation/?cid=fseprd526615&width=full>

Google maps



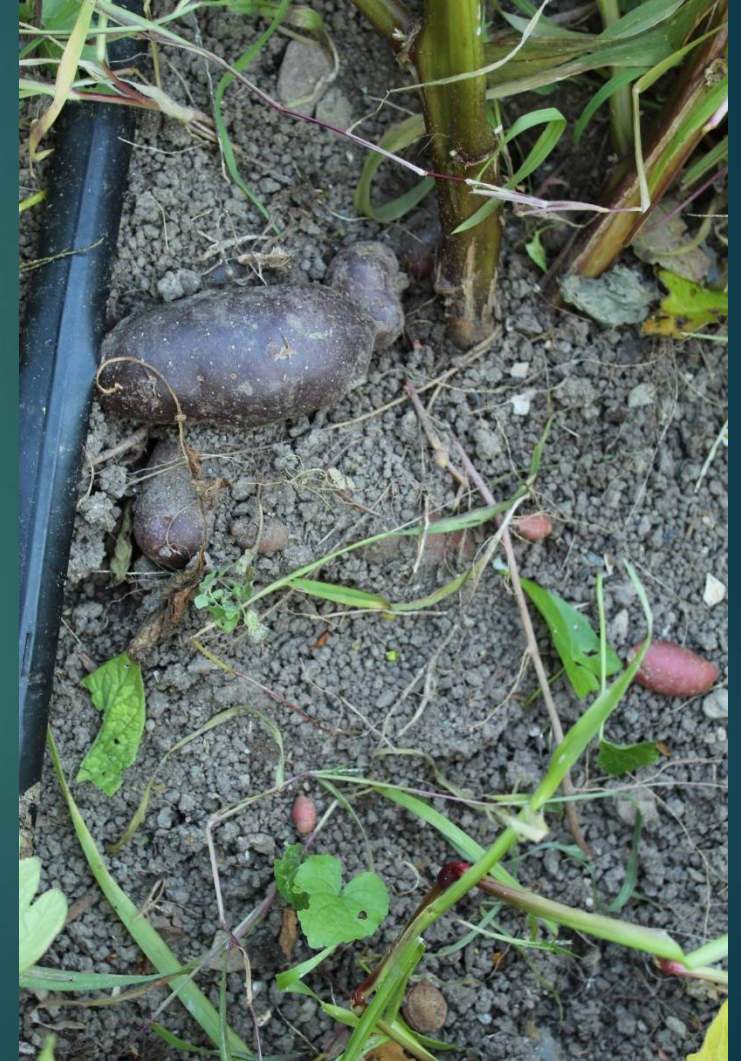
any  
gardens

Forest edge...

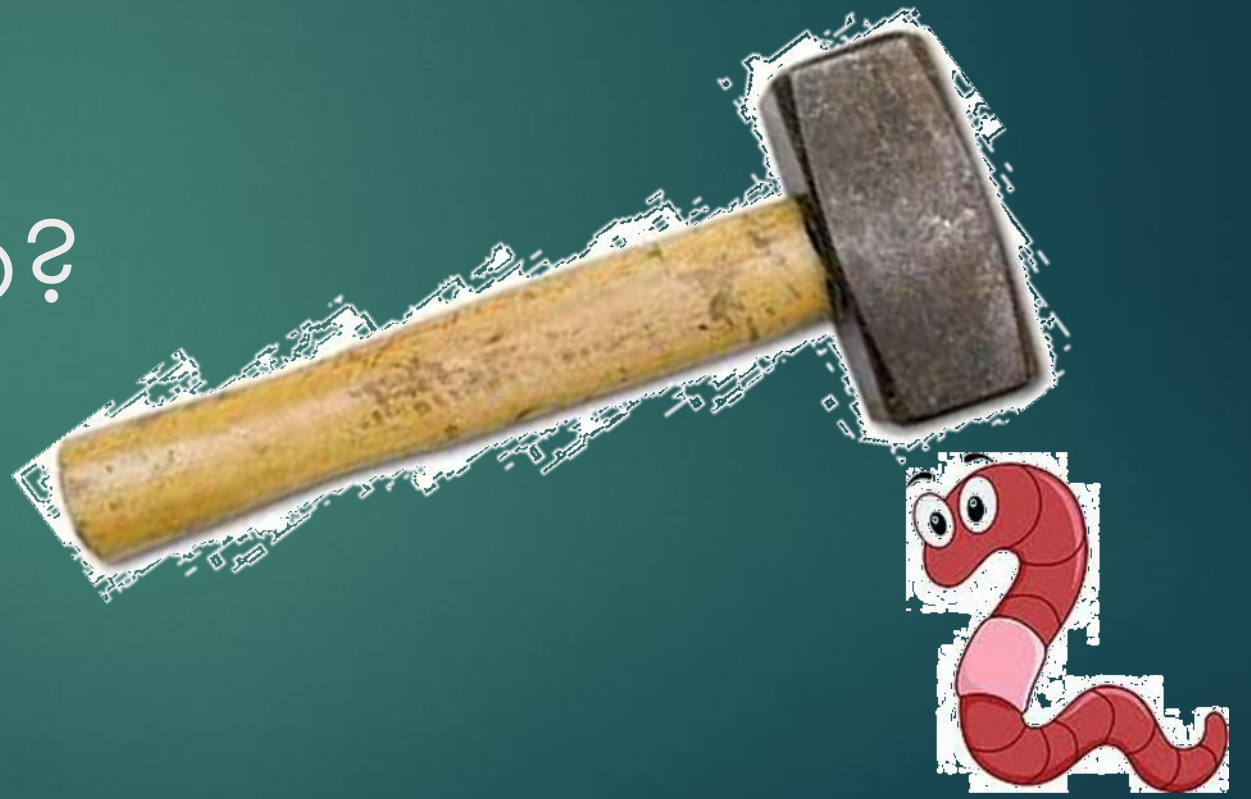


# Are also found in flower beds, lawns and potted plants.

- ▶ Lawn detaches
- ▶ Potted and bedded plants may show **drought symptoms and wilt**. Gardeners suspect fungal disease as the soil remains wet...
  - ▶ Worms feed on organic matter and thus reduce the contact between roots and soils
  - ▶ Half empty pots have been found
  - ▶ Reports have hostas and showy ladyslippers affected
  - ▶ Need more eyes on the ground to report suspicious plant damage
- ▶ Vegetable roots exposed ... e.g. my potatoes with greening of yellow potatoes and darkening skin of red potatoes.
- ▶ Economic damage has not been estimated



What can you do?



# How to control them if you already have them. There are no approved pesticides for earthworm!

- ▶ Precious little can be done ...
- ▶ BUT
- ▶ There is hope
  - ▶ Some fungi kill them
  - ▶ Some saponins kill them (soaps)
  - ▶ Needs to be explored more in research.... looking for funds
- ▶ Solarization of compost and mulch may help, but you have to get it hot enough.
- ▶ Don't use Sevin!!!! It kills everything else!



# State of Control Research at UVM

## Biocontrol

- ▶ Entomopathogenic fungi may hold some promise
- ▶ Naturally occurring vermicultural microorganisms have been isolated

## Chemical and physical agents

- ▶ Plants with high saponin content may kill worms
  - ▶ example Early Bird fertilizer contains saponins that are vermicultural. Discontinued by manufacturers.
  - ▶ Most plants contain these substances
  - ▶ Soap contains saponins!
- ▶ Irritants/Expellents
  - ▶ Mustard
- ▶ Sharp edged sands
- ▶ Biochar

# Bioassay

## Beauveria bassiana bioassay

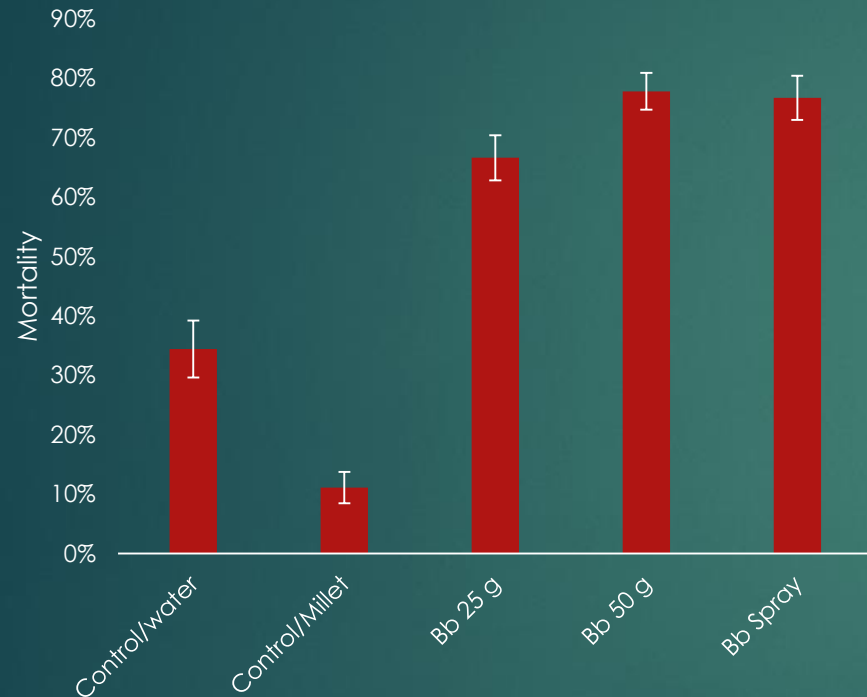


## Treatments

- ▶ With Beauveria Bassiana
  - ▶ Cultured B. bassiana
  - ▶ Botanigard
  - ▶ B. bassiana grown on millet (15 g and 25 g)
  - ▶ Controls

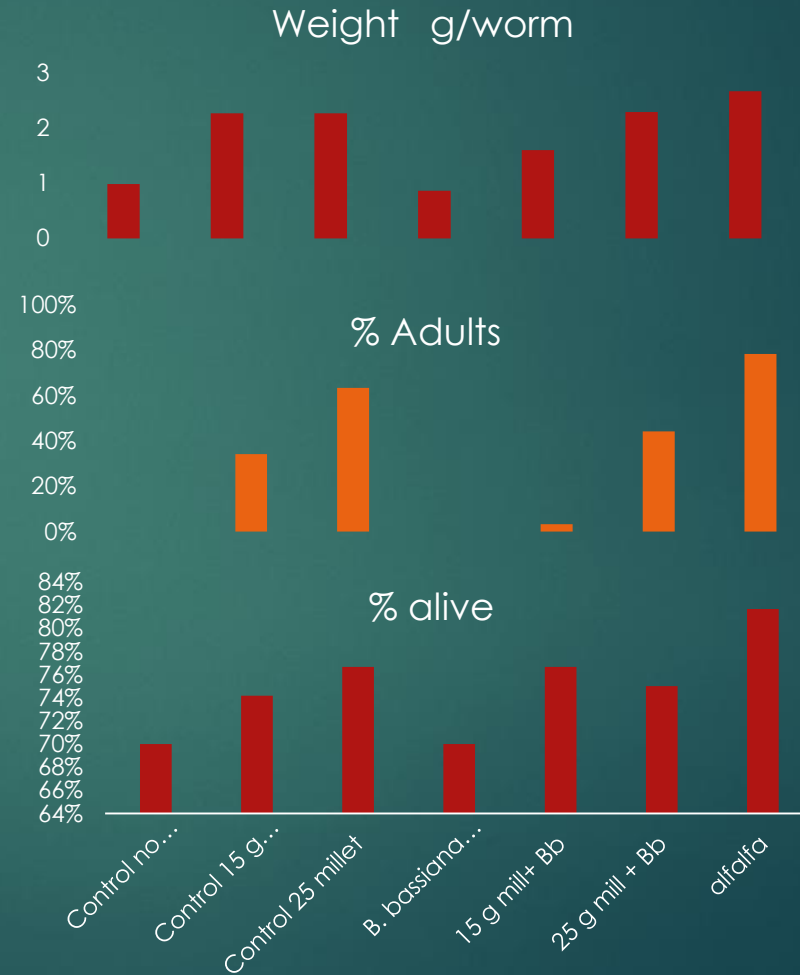
2018

Mortality of juveniles one month after exposure to *B. bassiana*



2019

Effect of old *B. bassiana* on juvenile snake worms



Results of bioassay



# Take home message from this experiment

- ▶ Don't use old biocontrol agents

BUT

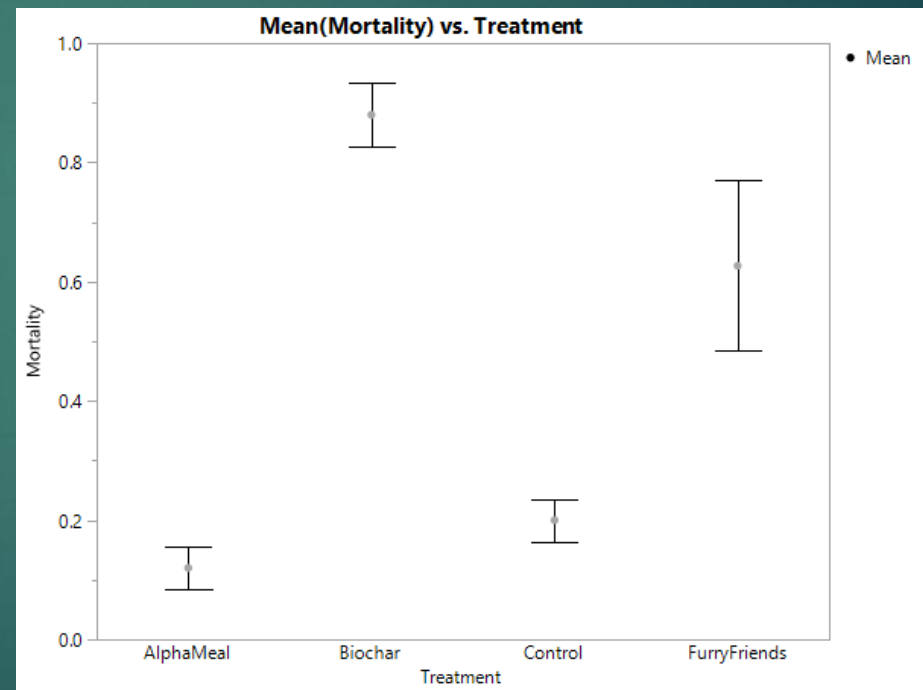
- ▶ Still had an effect on growth and maturation of pheretimoids
- ▶ **Seems that if no food is added the worms don't develop. – Don't feed your worms!!!!**
- ▶ Caution: Have not tried this in outdoor soils...
- ▶ No good consumer-friendly and effective formulations for worm control available yet. UVM, U. of Wisconsin and Colgate University are working on it

# Assays with Various Agents

## Treatments

- ▶ Control = nothing added to pots
- ▶ Biochar = 50 g of Biochar added to each pot
- ▶ Alphameal = 50 g of ground alfalfa meal
- ▶ Furry Friends = 50 g of alfalfa pellets
- ▶ 5 replications

## Results



Jean Campbell suggested Alfalfa ... but probably needs to be infected by fungi to work

# Other Findings

## Efficacy of isolates from dead earthworms

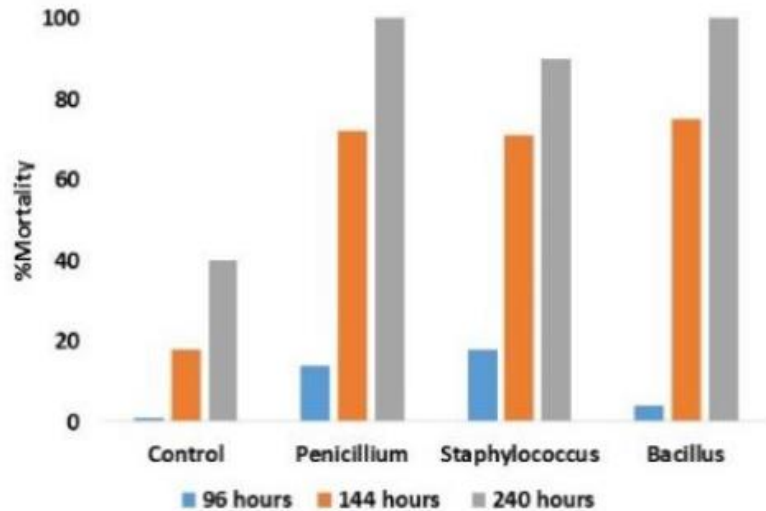


Figure 4: Vermicidal efficacy of different microbial isolates. Mortality of pheretimoids is similar in populations treated with three groups of microorganisms and significantly greater than in control populations.

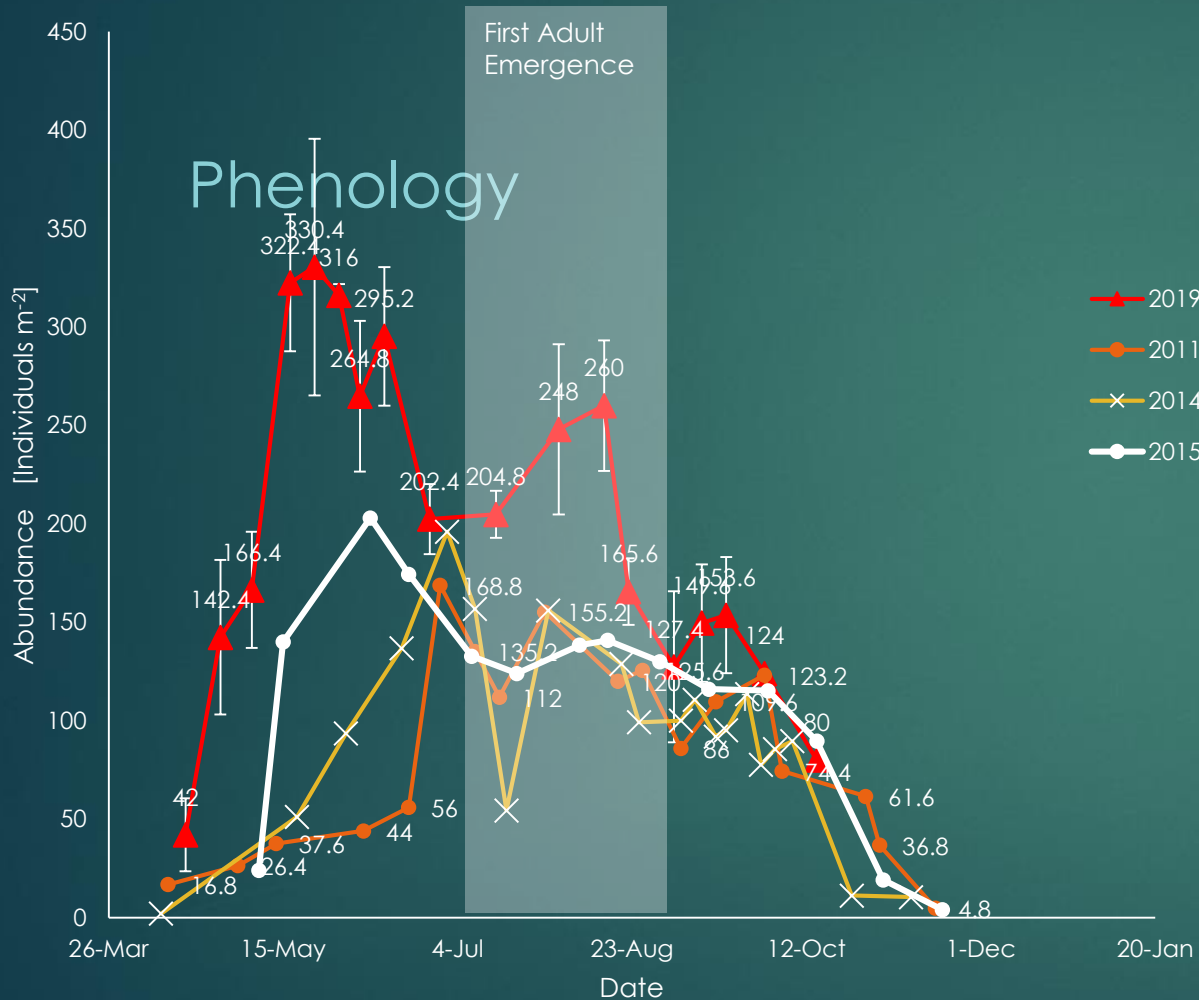
## Efficacy of other measures: Soap as a drench (Rita Buchanan)

- ▶ Couple of squirts into a dishpan, 15 minutes exposure = 100% mortality in 2 hours
- ▶ 2 minute drenches too short ...





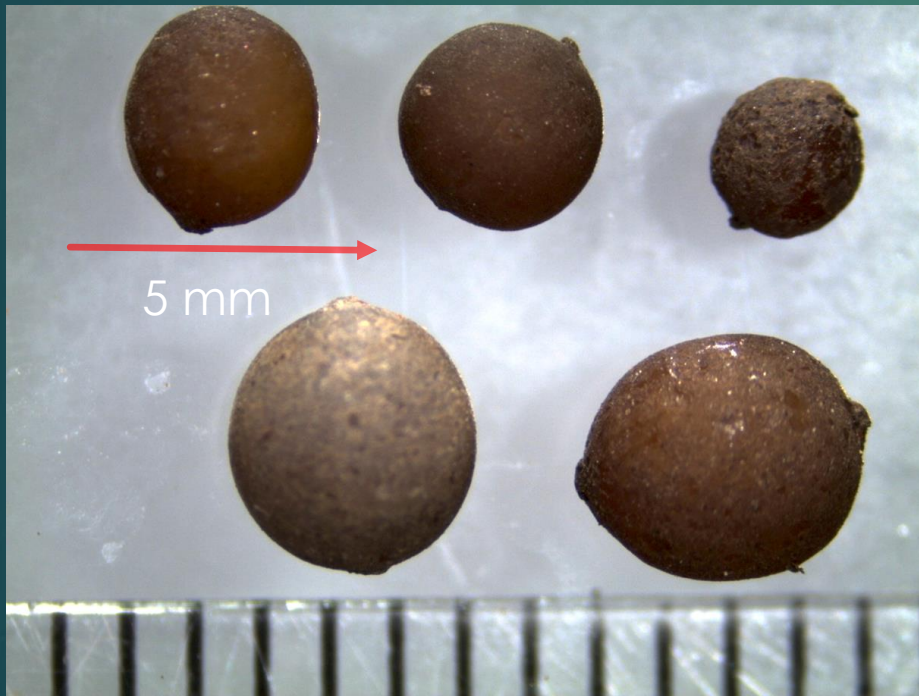
# When to apply any pixie dust



- ▶ Apply to control juveniles
- ▶ Measures that kill fast apply during peak in May or June
- ▶ Measures that kill slowly, also apply at peak density because you have a month from peak of juveniles to first adult.
- ▶ Repeat application maybe in August when there is a secondary peak.

# Cocoons – Trouble!

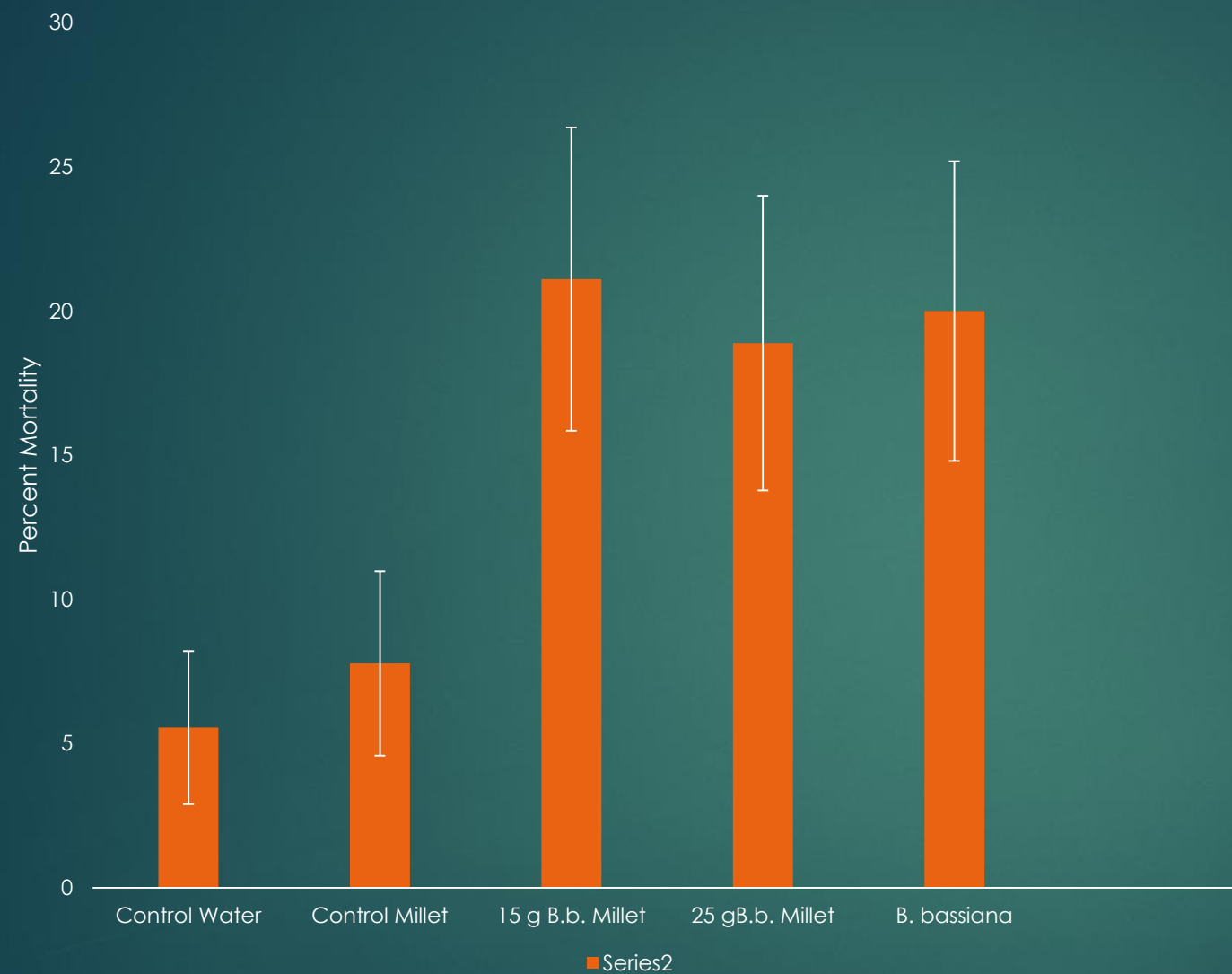
## Cocoons



## Survival structures

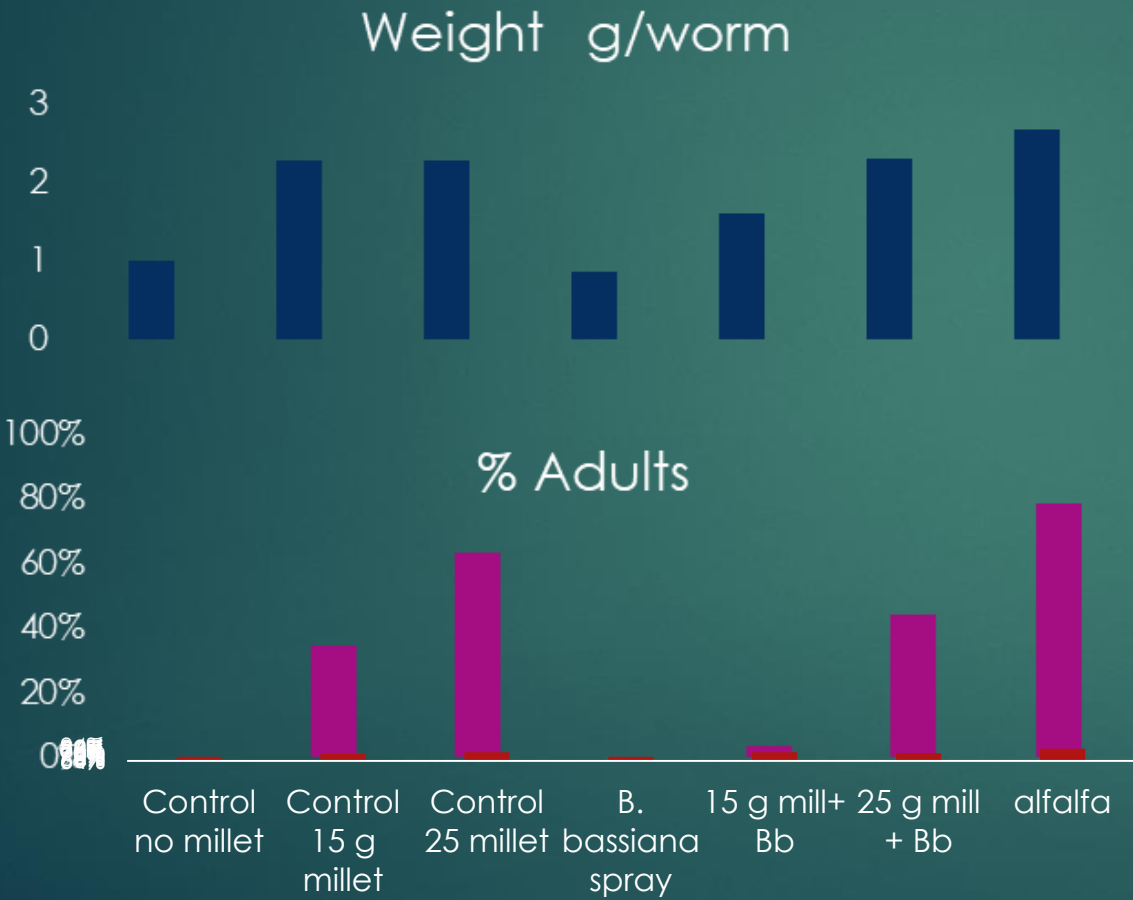
- ▶ Survive cold to at least  $-24\text{ C}$  ( $-12\text{ F}$ )
- ▶ Can survive drought
- ▶ Likely can stay viable for at least 2 years
- ▶ But will not tolerate heat above  $38\text{ C}$  ( $100\text{ F}$ ) (Johnson and Herrick, 2019)
- ▶ Difficult to control! – More work needed...

## Cocoon Mortality with *B. bassiana*





# Effect of organic amendments on worm development



Don't feed the worms

## Physical measures

Not tried yet ...

- ▶ Solarization:
- ▶ Clear Plastic
- ▶ Best for compost and mulches but you need to spread them thinly on a hard surface where the worms don't have a way out
- ▶ Spread compost thinly as these materials are good insulators and the worms would have an escape if the amendments are spread too thick...
- ▶ Collect as many as possible

## Physical Measures II

Not very realistic ...

- ▶ Create anaerobic conditions
- ▶ Put mulch or compost in a container that you can seal. Wet compost, seal and leave for a week or two. Maybe large, thick garbage bags or large rain barrel like 50-gal drums with a lid you can seal may work. Place in the sun.
- ▶ Try to make bokashi instead of thermophilic compost



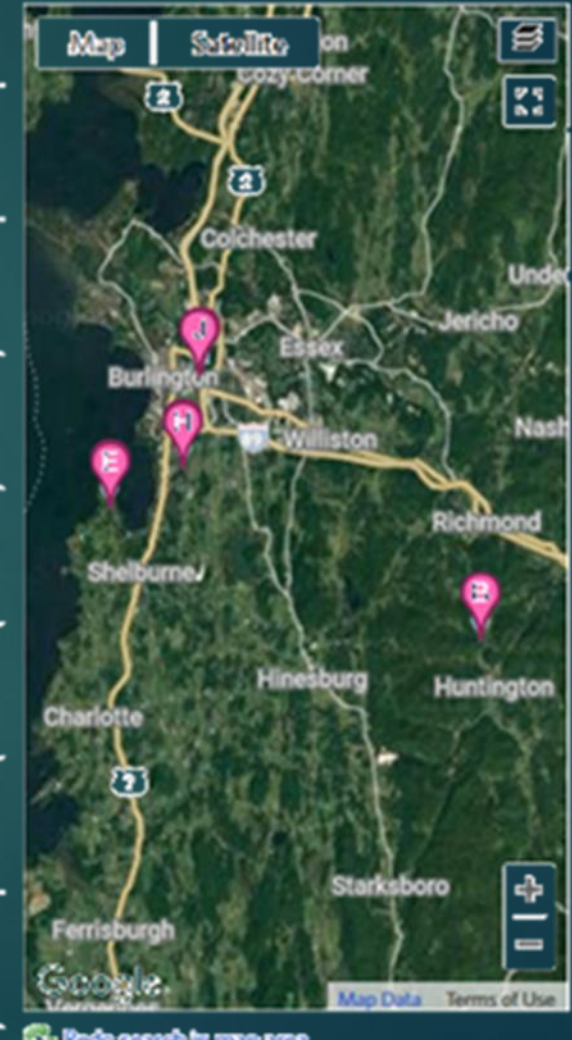
# Combined Interventions

Cumulative effects

- ▶ Not one single measure will manage populations well
- ▶ Combine measures.
- ▶ We have to try this on the landscape scale and for a longer period of time (two or three years)
- ▶ Don't feed + pixie dust + other measure

# Reporting the worms: Citizen Scientists: uScientists

INATURALIST – A GEOGRAPHIC REPORTING TOOL FOR SPECIES...



# Identification

How can you identify the three likely Vermont pheretimoid species?

Best when they are adult, two levels possible depending on how confident you are.

To pheretimoid (simple)

To species (simple but not as easy)





Picture credits: Maryam Nouri-Aiin

*M. hilgendorfi*

*A. agrestis*

*A. tokioensis*



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(4.29 –6.69 inch)

Size 70–160 mm  
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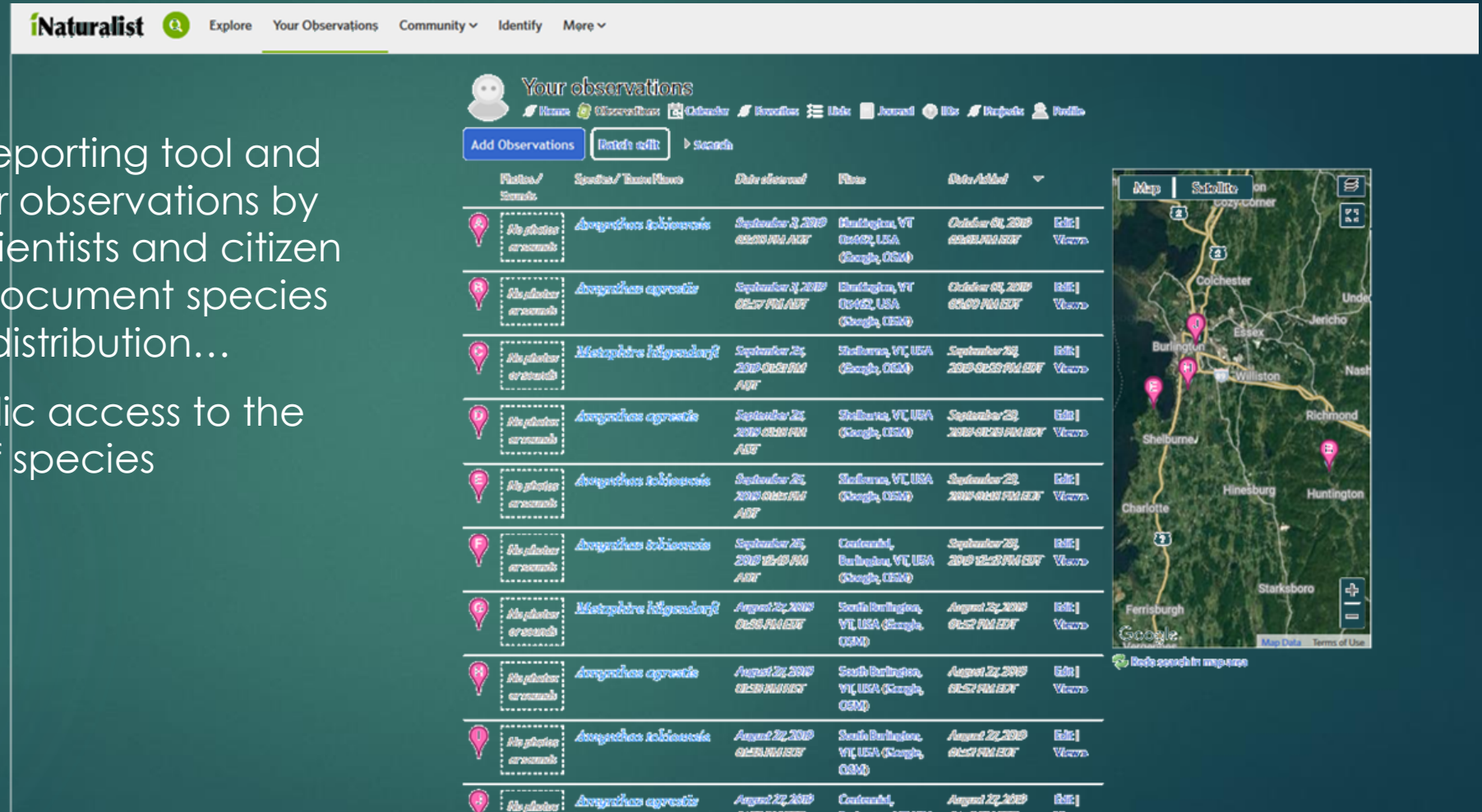
# Identification: simple key for Vermont pheretimoids; but, may not work elsewhere in the same way

- ▶ Is the worm an adult? i.e., does it have a clitellum?
  - ▶ Does the clitellum go all around the body? Yes, go to Pheretimid
    - ▶ No European earthworm
- ▶ Pheretimoids
- ▶ Is the worm shorter than 2.5 inches long and slim?
  - ▶ Yes, Likely *Amyntas tokioensis*
- ▶ No, Is the worm longer than 10 cm?
  - ▶ Does the worm have two clear, distinct genital markings several segments in front of clitellum? (visible to naked eye). Yes, then *Metaphire hilgendorfi*
  - ▶ Else, *Amyntas agrestis*.



# What is iNaturalist

- ▶ World-wide reporting tool and data base for observations by naturalists, scientists and citizen scientists to document species geographic distribution...
- ▶ Provides public access to the distribution of species



The screenshot displays the iNaturalist website interface. At the top, the navigation bar includes the iNaturalist logo, a search icon, and links for Explore, Your Observations, Community, Identify, and More. Below the navigation bar, the 'Your observations' section is visible, featuring a user profile icon, a list of observation types (Observations, Observations, Observations, Observations), and buttons for 'Add Observations', 'Filter all', and 'Search'.

The main content area shows a table of observations with the following columns: Photos/Search, Species/Taxon Name, Date observed, Place, Date added, and a dropdown menu. The table lists several observations of *Asperula tobiensis* and *Asperula cynanchica* in Burlington, VT, USA, with dates ranging from August 22, 2019, to September 29, 2019. Each observation entry includes a red location pin icon, a thumbnail image of the plant, and links for 'Edit' and 'View'.

On the right side of the page, there is a map showing the location of the observations in Burlington, VT, USA. The map includes a search bar, a 'Map' button, and a 'Satellite' button. The map shows the city of Burlington and surrounding areas, with a red location pin indicating the location of the observations. The map also includes a 'Map Data' button and a 'Terms of Use' link.



# There are iNaturalist smart phone apps of for real time reporting... .

## iPhone

- ▶ At the Apple store
- ▶ Allows pictures of worms to be posted (I can check identification)
- ▶ Take picture of underside of worm with good magnification
- ▶ You may have to calm or restrain the worm
- ▶ Take pictures with an object of known size: dime or quarter
- ▶ You can post directly from phone

## Android Smart Phones

- ▶ At Google play
- ▶ Allows pictures of worms to be posted (I can check identification)
- ▶ Take picture of underside of the worm
- ▶ You may have to calm or restrain the worm
- ▶ Take pictures with an object of known size: dime or quarter
- ▶ You can post directly from phone

# Lets go to iNaturalist

First step is to sign up

- ▶ <https://www.inaturalist.org>
- ▶ E-mail as your ID
- ▶ Password
- ▶ Create a profile...
- ▶ Then you can add pheretimoid species or other taxa... lets check it out...



Questions?