Interannual patterns and drivers of dispersal in aquatic beetles

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Dispersal

- Movement of individuals among habitats that has the potential to lead to gene flow
  - From birth sites to breeding sites
  - Among breeding sites

Occurs when:

- Certain life history stages are reached
  - i.e. pupation

and/or

- Environmental conditions cue movement from a habitat patch
  - Temperature
  - Moisture

Timing of Dispersal

Dispersal is often timed to match:

- Resource availability
- Mate availability
- Weather patterns
- Physiological constraints

- Mismatch between dispersal and these factors can lead to:
  - Reduced individual fitness (including death)
  - Changes in population sizes
  - Changes in community structure and function

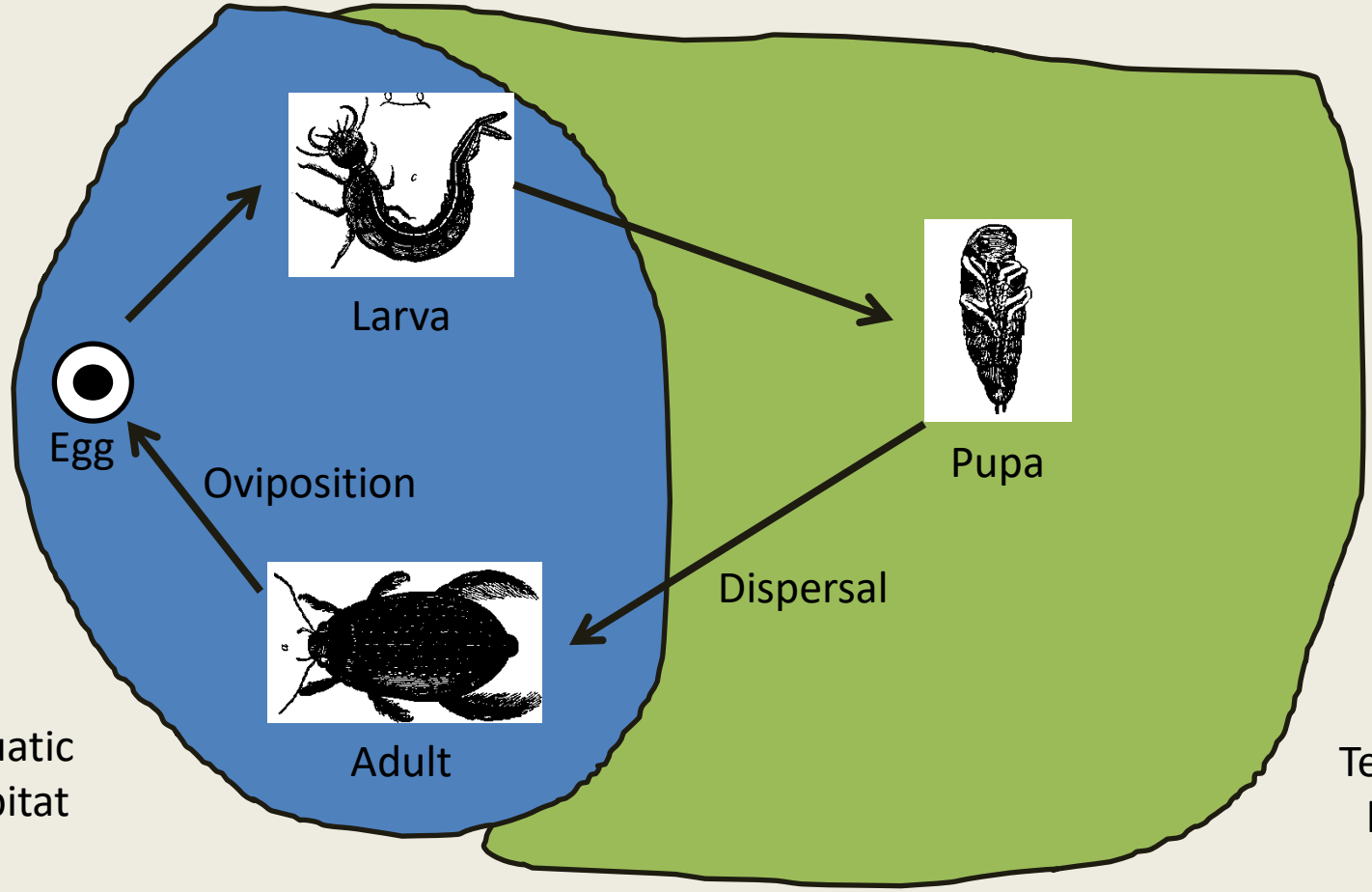
Why aquatic beetles?

- Live in discrete habitats (ponds, streams)
- Speciose (12,600 species worldwide)
- Form highly diverse assemblages in small habitats
- Readily colonize experimental mesocosms
- Have complex life cycles with obligate dispersal

Thermonectus nigrofasciatus

Dytiscus carolinus

Aquatic beetle life cycle



This is a generalized example, representative of many common taxa. Whether one phase is terrestrial or aquatic varies by taxa.

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Larva → Pupa → Adult

- Aquatic larvae crawl out of water, select pupation sites near natal pond edge
- Duration of pupa stage varies, but can include dormancy/diapause if conditions are not favorable for completion
- Upon emergence from pupation sites, adults fly across terrestrial habitat to select aquatic breeding sites

Larva

Pupa

Habitat selection

- Dispersing adult beetles select habitats both for themselves (to obtain resources) and for their offspring (they breed in the same habitats)
- The process of habitat selection is a dominant component of fitness and community structure
- Selecting poor habitats (few resources, predators, short hydroperiods) reduces expected fitness

Why is habitat selection so critical?

- Often after initial dispersal from pupation sites is complete, adult beetles autolyze wing muscles to gain energy for reproduction
  - They cannot disperse to new habitats if conditions change
  - Their entire lifetime reproductive output will be focused in the single habitat they select
- A determinant of community/assemblage structure

Hypotheses:

- Some species will exhibit regular, interannual dispersal patterns
- Precipitation and temperature will be seasonally important drivers of dispersal
- Changes in dispersal will result in different beetle assemblages

Objectives:

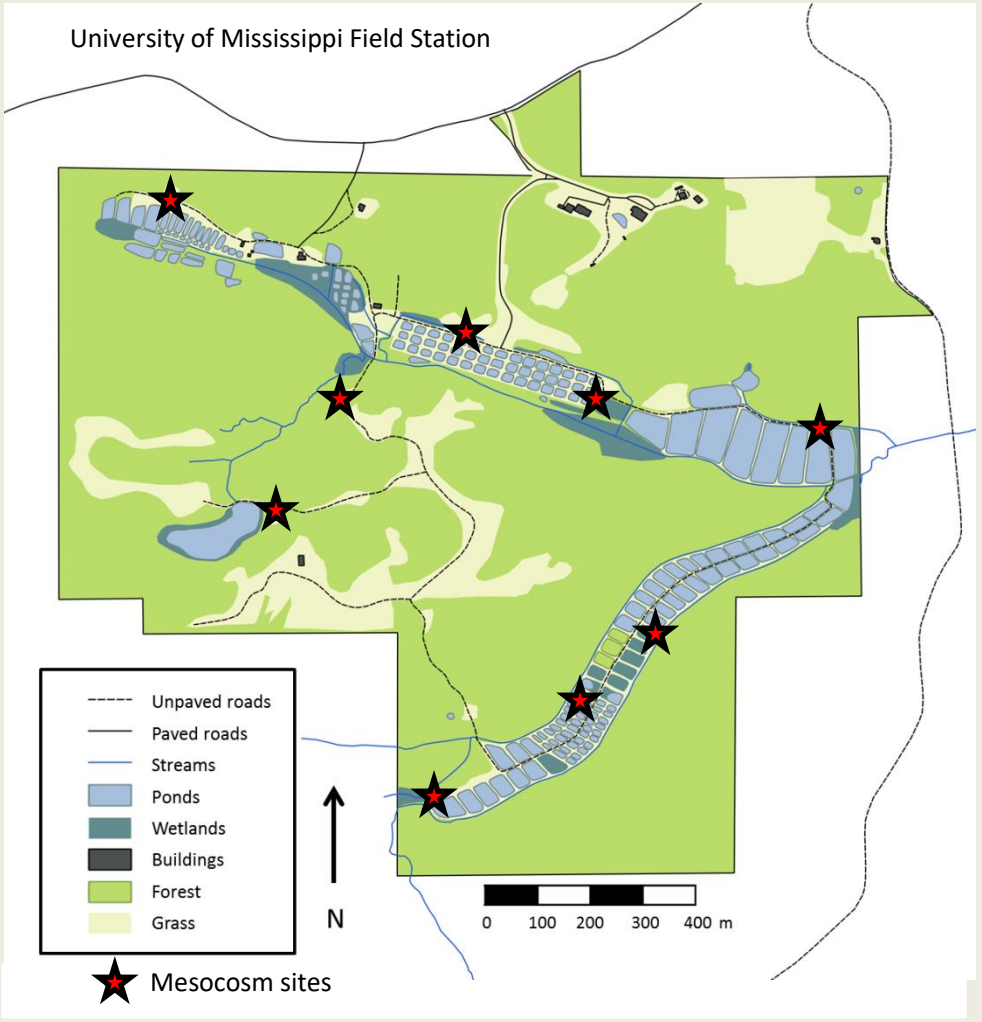
1. Determine temporal patterns of aquatic beetle dispersal and related assemblage structure
2. Assess the relative influence of climatic factors on dispersal patterns within and among years

Mesocosms

- Plastic wading pools (110 L)
- Add 0.5 kg leaf litter as a resource base
- Fill with well water
- Cover with fiberglass screen to separate beetles from leaf litter
- Collect all beetles weekly, preserve, and identify

Study design

- Establish sets of 3 mesocosms at 9 sites across the University of Mississippi Field Station in May 2016
- Sites were chosen to cover a large spatial area
- Optimized proximity to suitable natural aquatic habitats
- Each site has a data logger to measure:
  - Water temperature
  - Light levels



Additional data

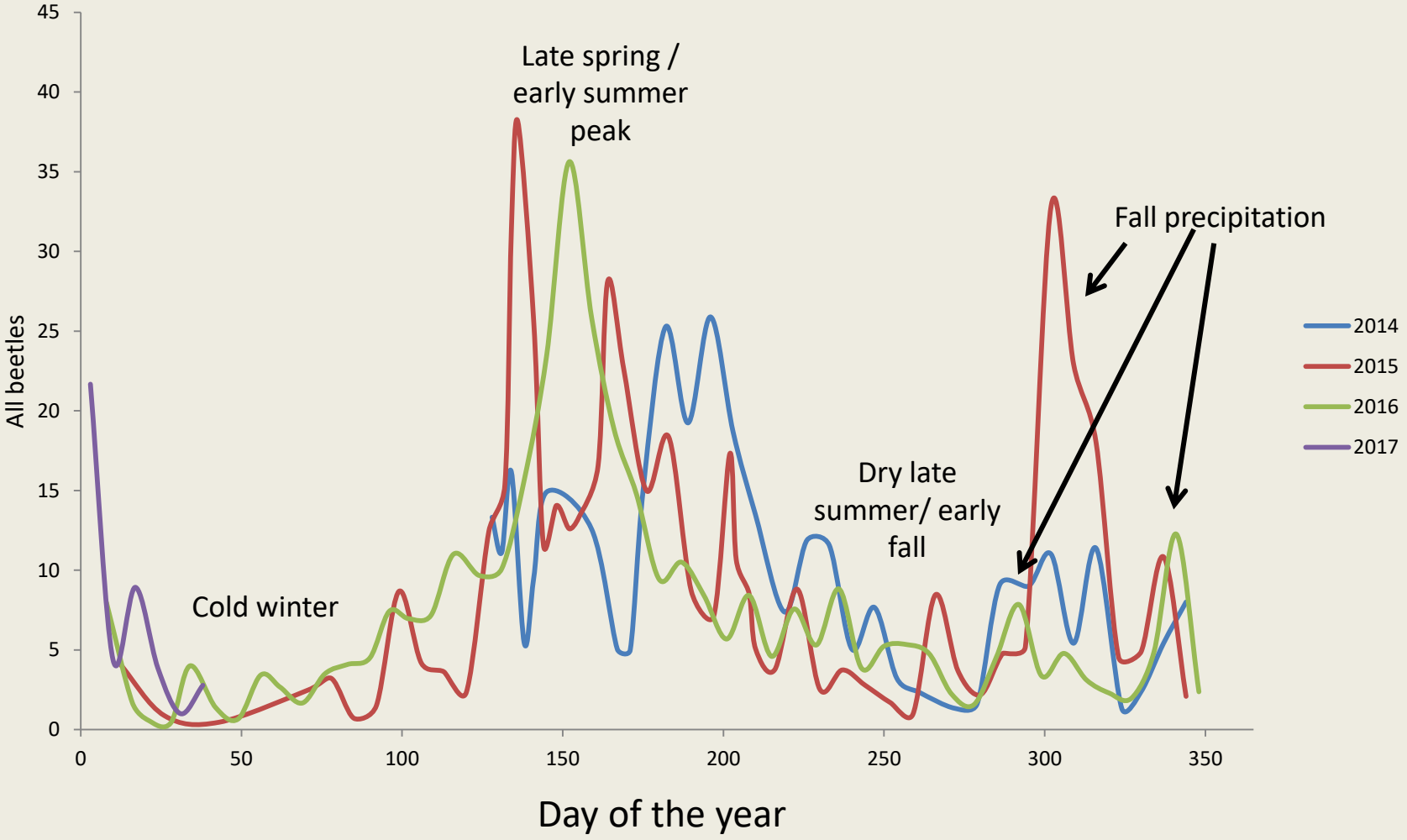
- Rain gauge records precipitation
- Another data logger records air temperature
- Measure pool conditions at time of each collection (DO, conductivity)
- Monitor timing of pond drying at UMFS
- In addition to the mesocosms established in May 2016, I have data from experiments at UMFS beginning in May 2014, forming almost three complete years of weekly beetle sampling
  - Data from nearby NOAA weather stations will fill in gaps in precipitation and temperature data

Preliminary results

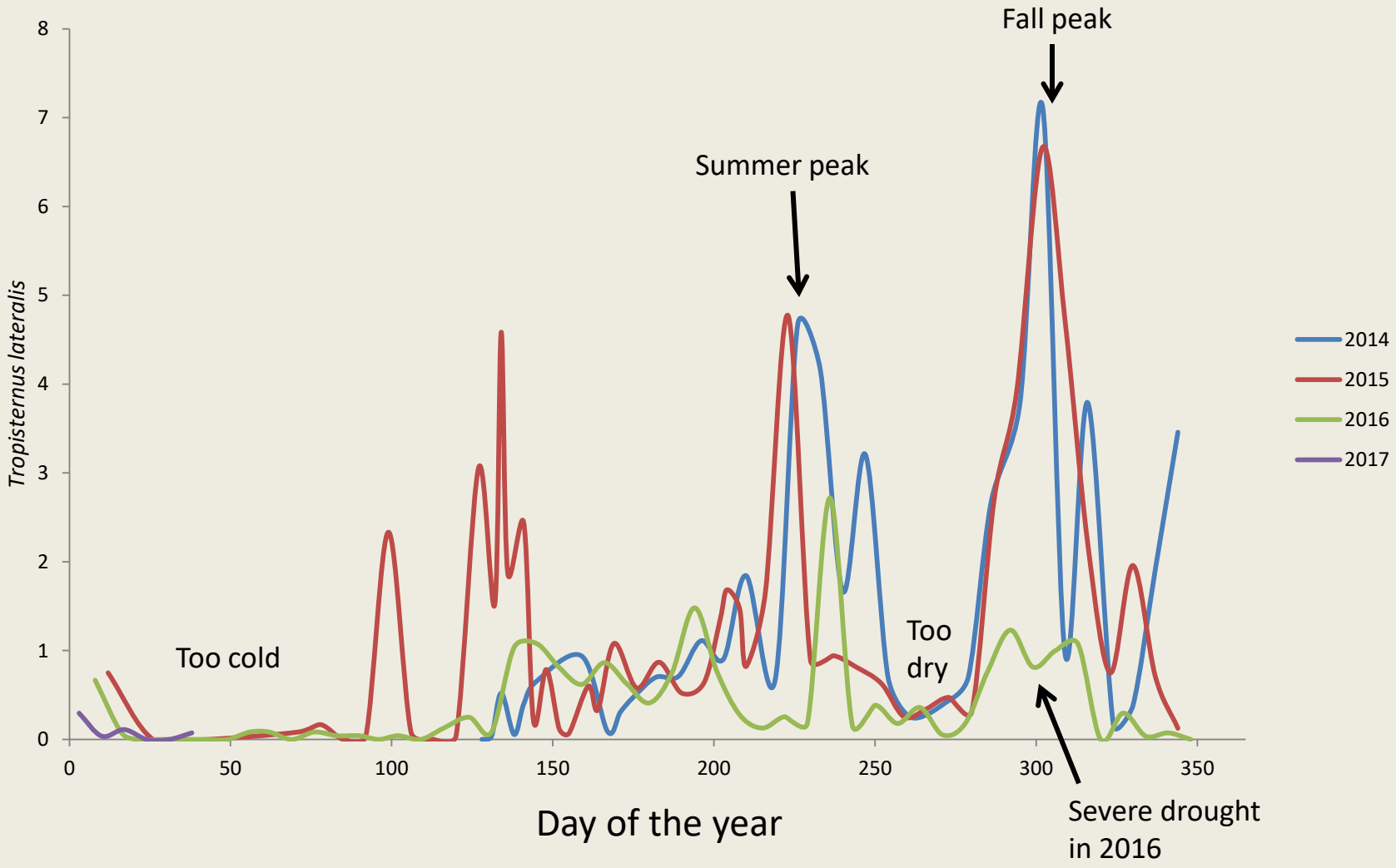
- From 8 May 2014 through 7 February 2017, mesocosms were colonized by 54,089 beetles representing 94 species
- Results are preliminary, work is continuing, and considerably more work needs to be done to assess all species and possible factors

- Figures on the following slides show the average number of beetles per mesocosm
- Points on these figures have error bars, but they are not shown for clarity

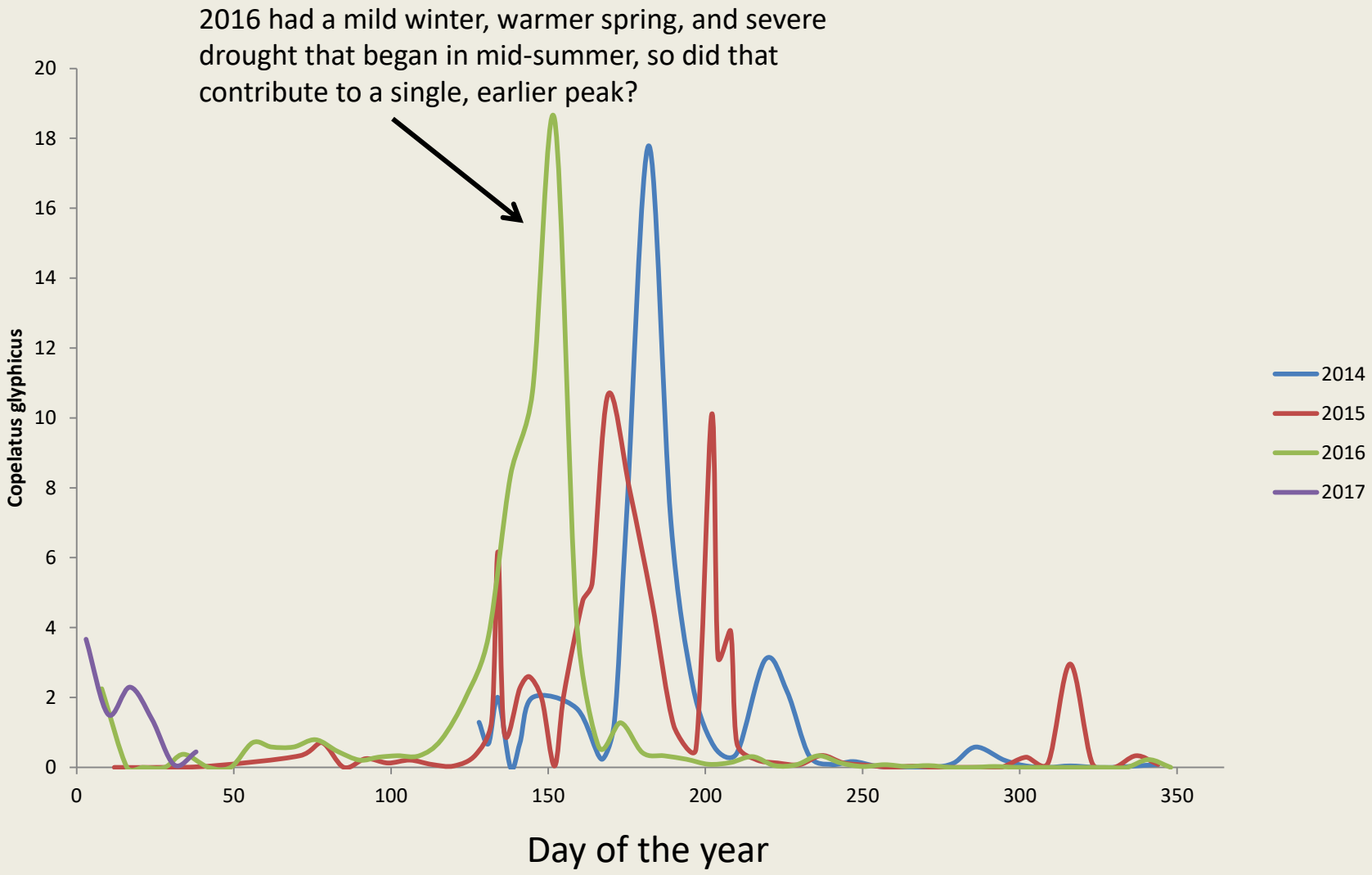
The total number of dispersing beetles reaches its peak in late spring/early summer, with low abundances in the cold period of winter and dry period of late summer/early fall. There is a typically smaller precipitation-driven peak in late fall.



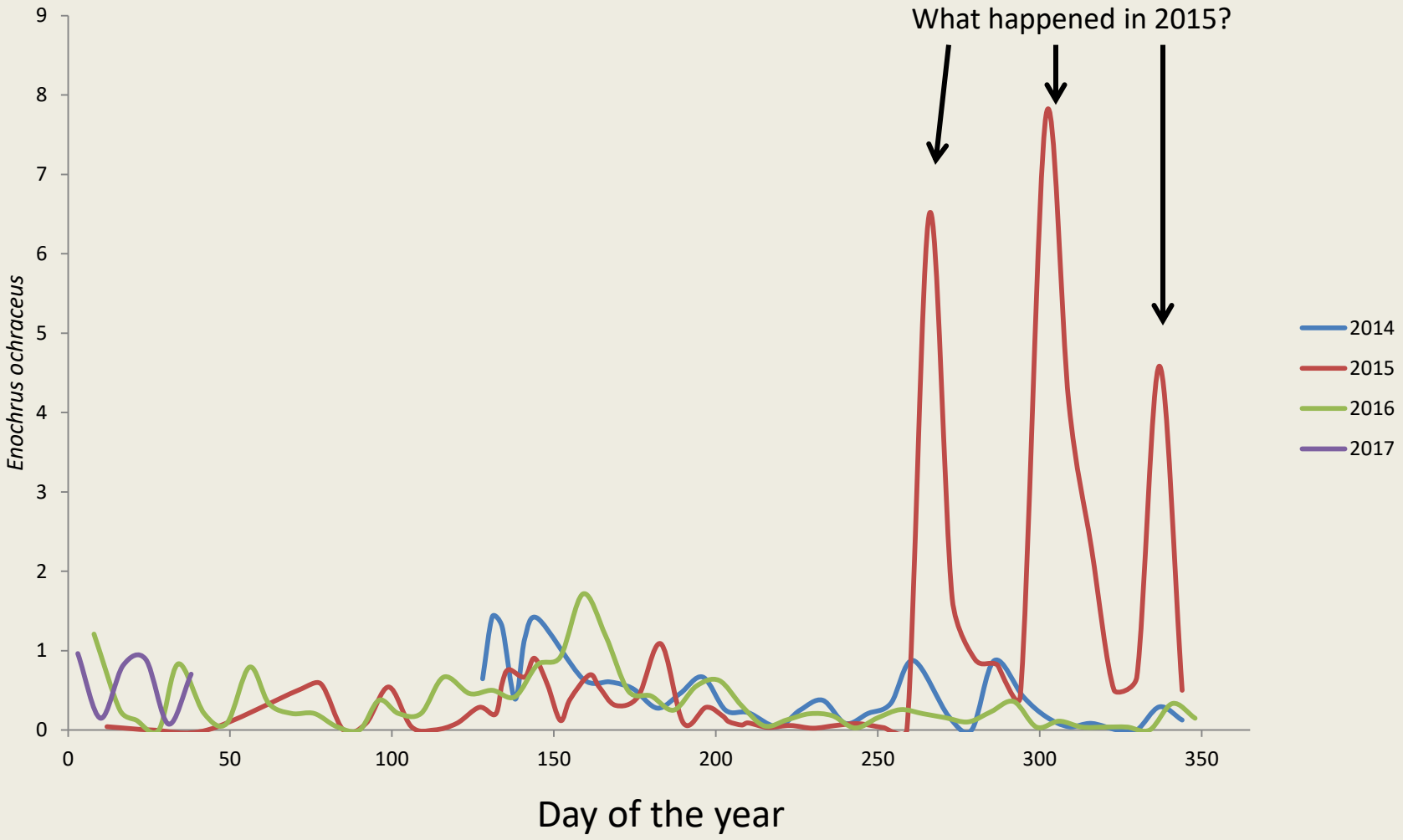
Many species have relatively clear seasonal patterns of dispersal. *Tropisternus lateralis* disperses in moderate abundances in spring/early summer, with peaks in mid summer and mid fall.



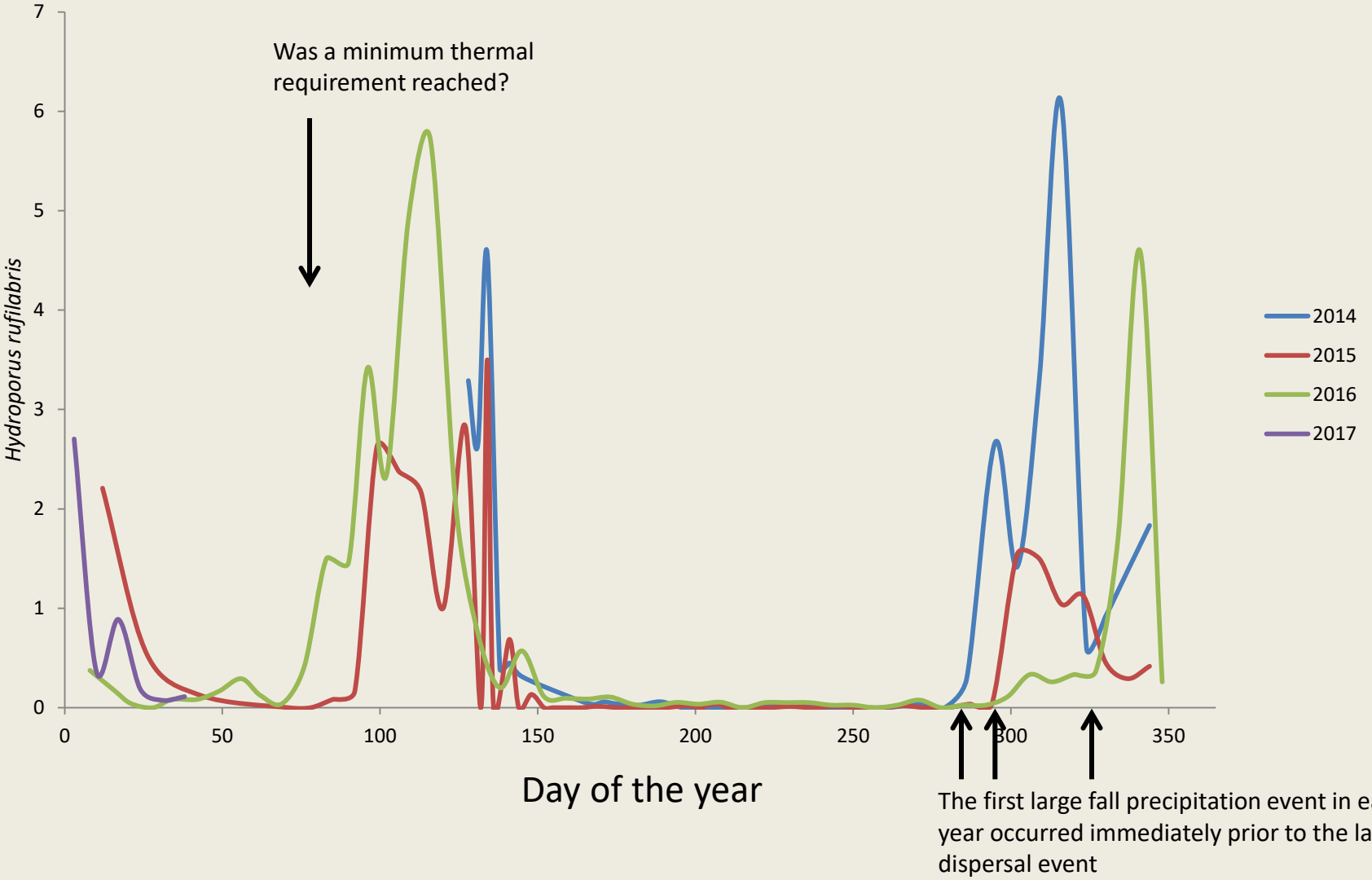
Copelatus glyphicus, the most common species, has a large late spring/early summer peak, while being relatively uncommon the rest of the year.



Other species, such as *Enochrus ochraceus*, have no clear dispersal events and/or have large events that don't repeat between years.



Some species, such as *Hydroporus rufilibris*, display not only strong seasonal dispersal events, but the fall event clearly occurs after a large precipitation event

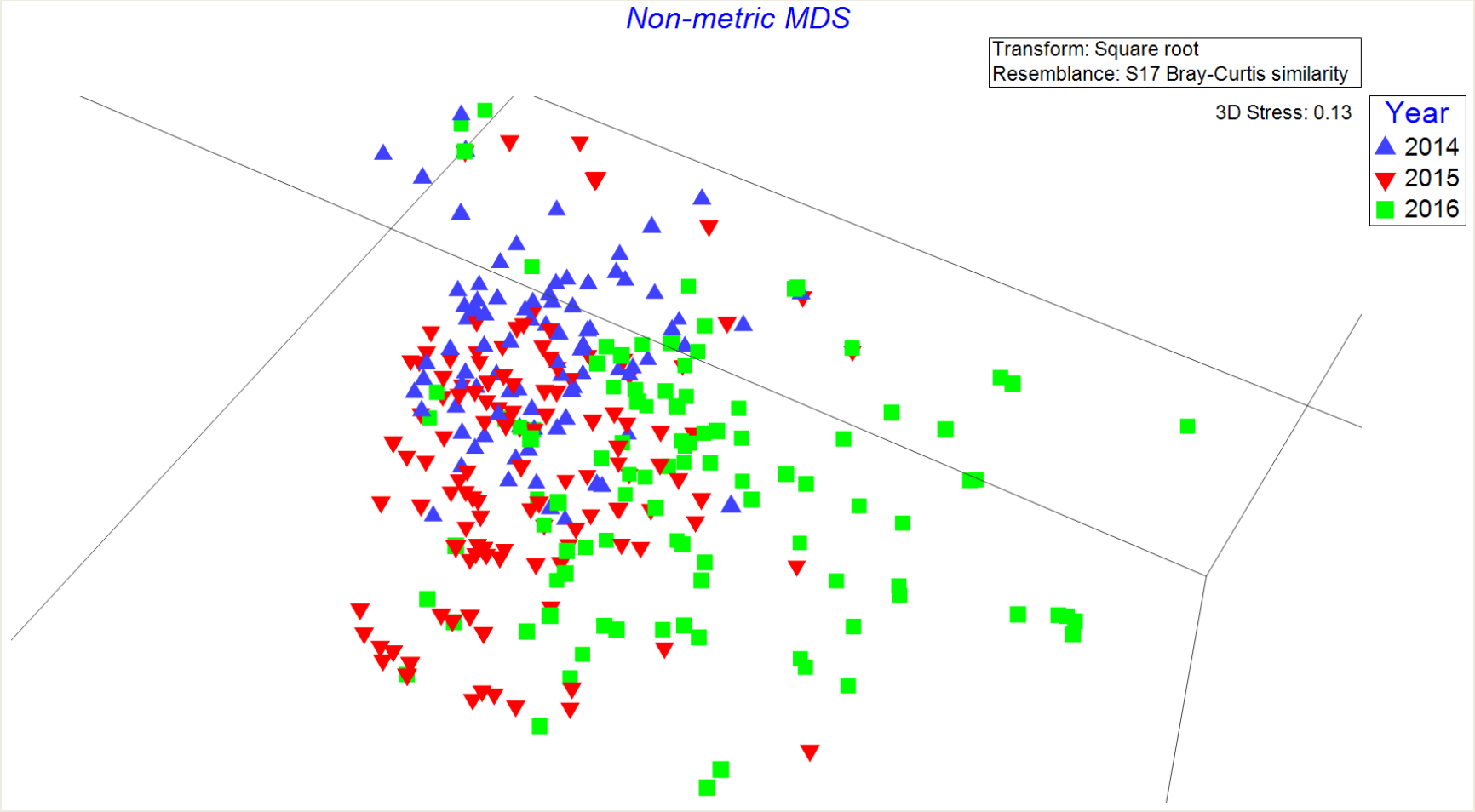


Assemblage structure

- Preliminary assemblage analyses show that year-to-year variability in dispersal creates distinct assemblages of dispersing beetles each year
- Assemblages in fall 2016 (drought year) were the most distinct, when comparing the assemblages between years
- Assemblages in early summer 2016 (prior to drought) were not nearly as distinct distinct from other years as with fall assemblages

This NMDS plot visualizes assemblage structure. Each point is a multidimensional representation of the assemblage in one mesocosm plotted in 3D space.

When you to rotate the 3D figure, you're able more clearly to see that the placement of 2016 points is much more distinct than the placement of 2014 and 2015 points, representing the drought-induced highly distinct assemblages in 2016.



Future directions

- Continue collecting to look for further changes
- Precipitation is really a proxy for what may be a more direct driver of dispersal from pupation sites:
  - Soil moisture – need to get a meter to measure

Conclusions

- Dispersal patterns are often species-specific
- The most common trend is for a large dispersal event in late spring followed by a smaller one in late fall
- Precipitation is an important driver of dispersal in late summer/fall, whereas temperature is dominant in winter/early spring

Conclusions

- Species-specific responses to variation in weather conditions create distinct beetle assemblages between years
- But does this affect interspecific interactions and community functioning?
  - Functional roles of aquatic beetles are very poorly understood

Significance

- The observed weather-related changes in dispersal have wide-ranging implications for dispersal, populations, and community structure, particularly as climate change progresses
  - Can pupating beetles remain dormant long enough to outlast dry periods?
  - Or do temperatures rise enough to support greater winter, early spring, or late fall dispersal?
  - Does this lead to species range shifts?
  - How does aquatic community function change as the composition of dispersing beetle assemblages changes?

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