

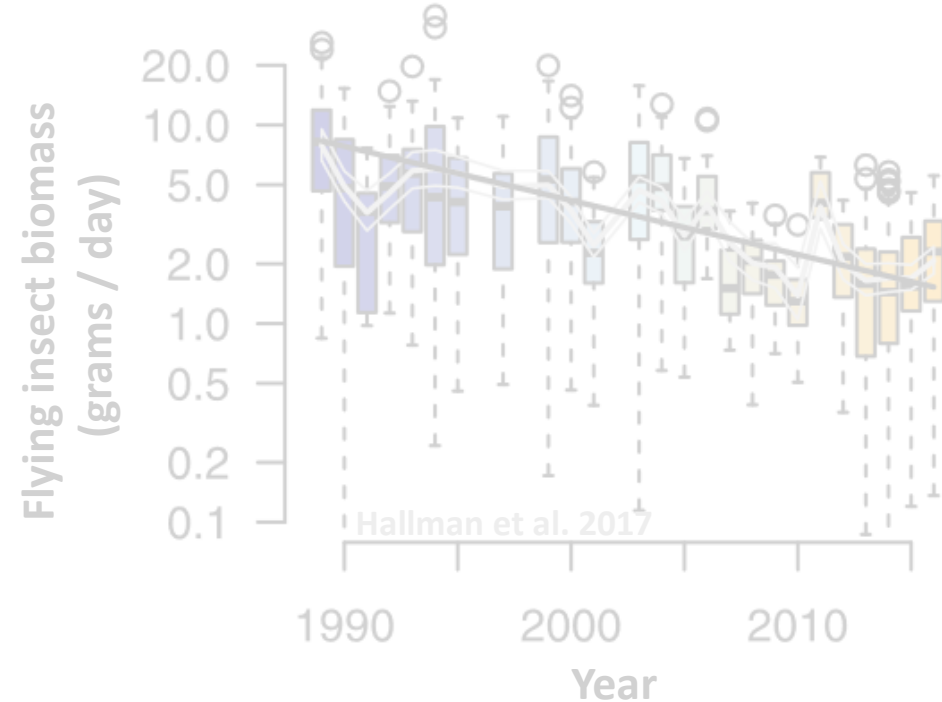
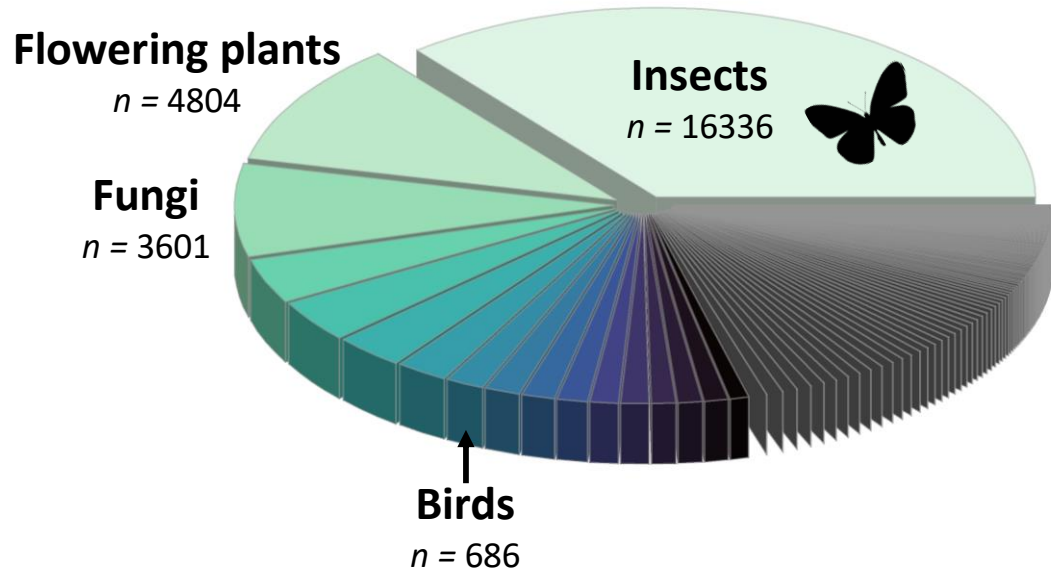
Living on the edge in a warming world: *Mapping distributions & thermal refugia of forest insects across the northeastern United States*

Michael T. Hallworth, Spencer Hardy, Jason Loomis,
Nathaniel Sharp, Julia Pupko, Ryan Rebozo & Kent P. McFarland

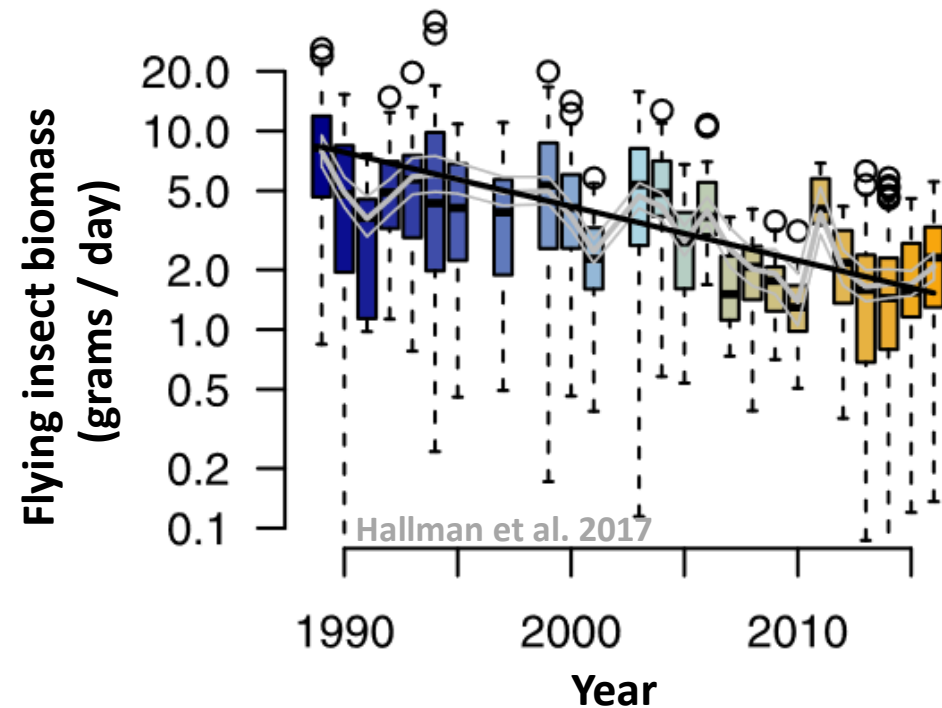
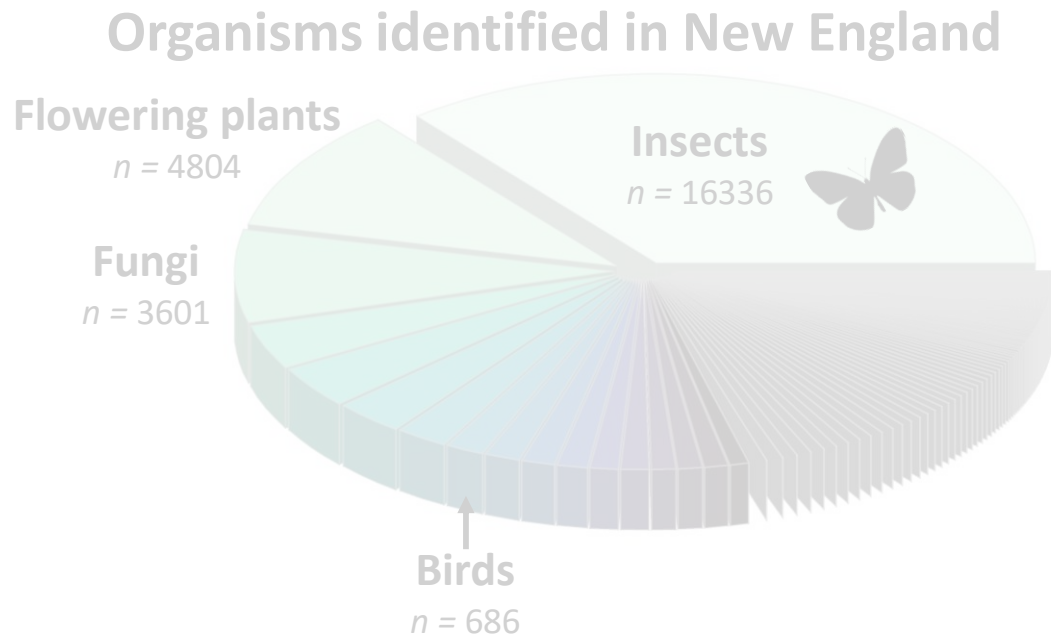
Insects, the world's most species-rich and abundant group of macroscopic organisms, are **experiencing precipitous declines**



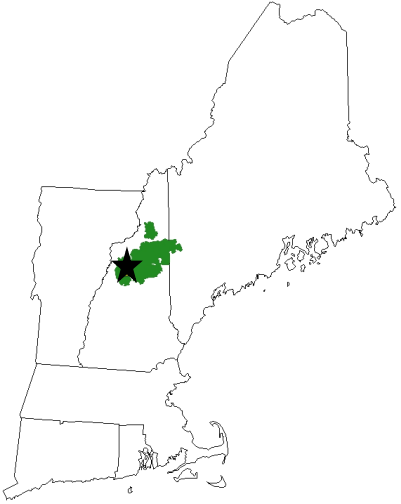
Organisms identified in New England



Insects, the world's most species-rich and abundant group of macroscopic organisms, are **experiencing precipitous declines**

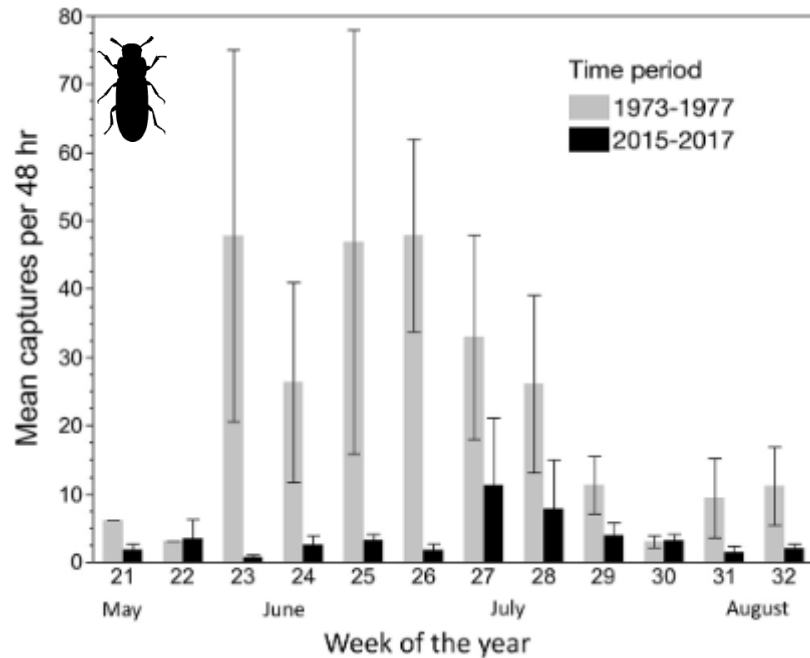


Observed beetle declines within New England

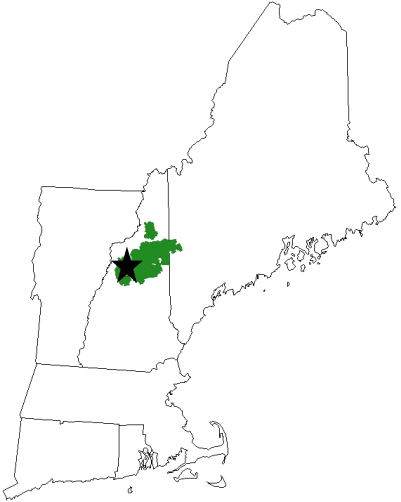


Window trap surveys 1970s
Replicated surveys 2015-2017
Harris et al. 2019

Decline in abundance

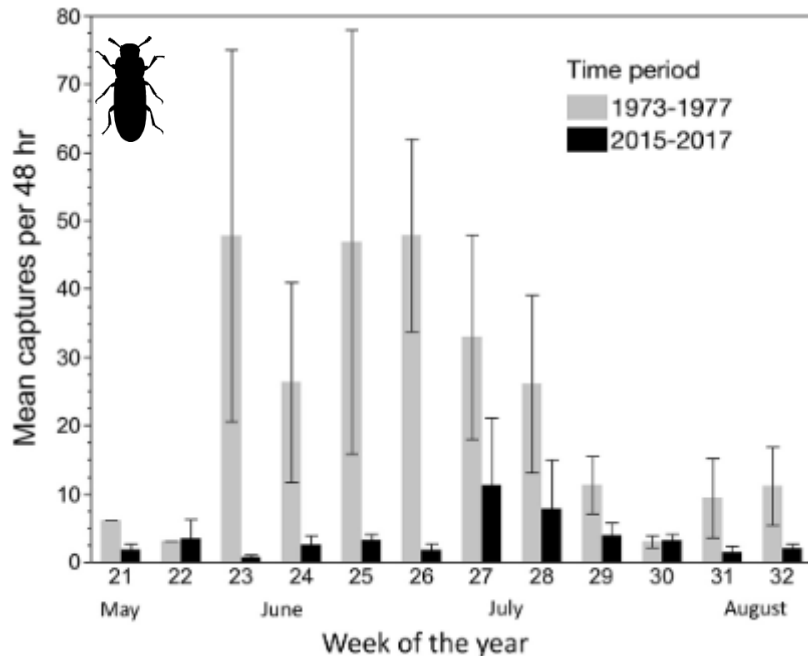


Observed beetle declines within New England

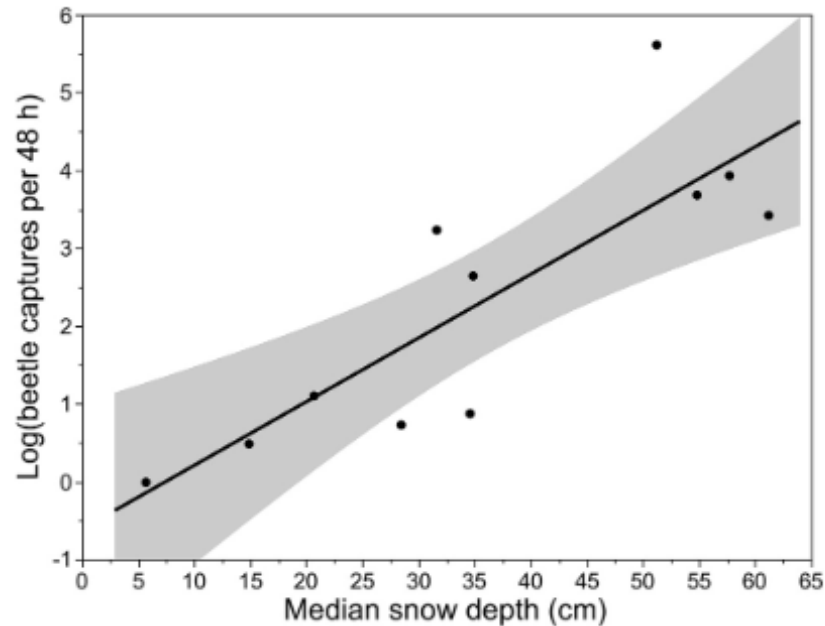


Window trap surveys 1970s
Replicated surveys 2015-2017
Harris et al. 2019

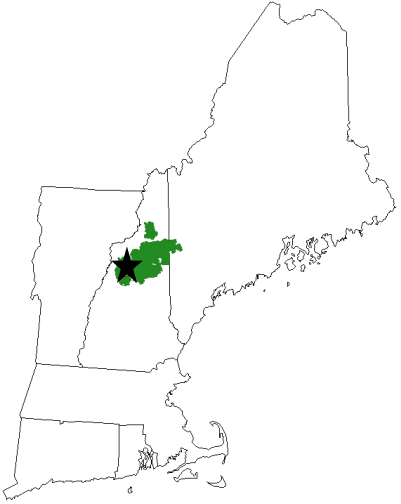
Decline in abundance



correlated with snow depth



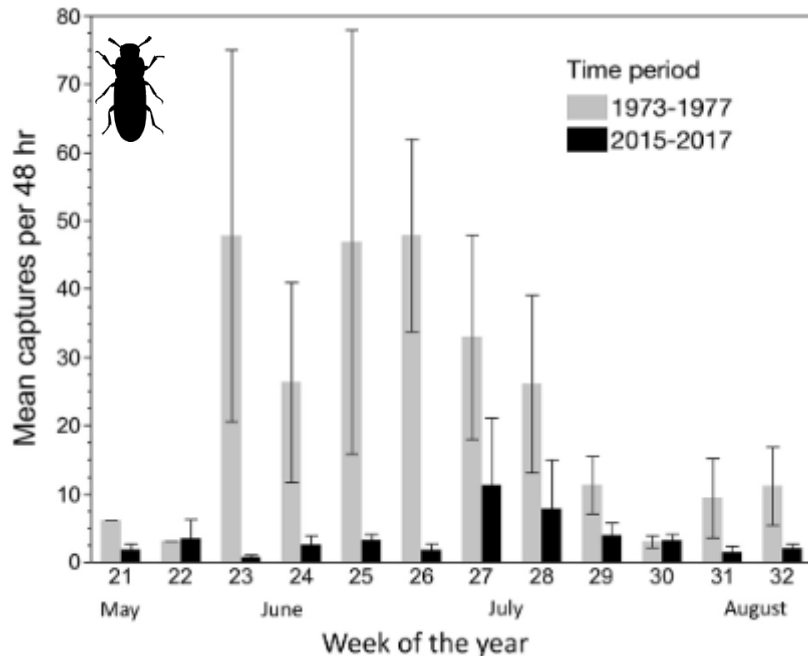
Observed beetle declines within New England



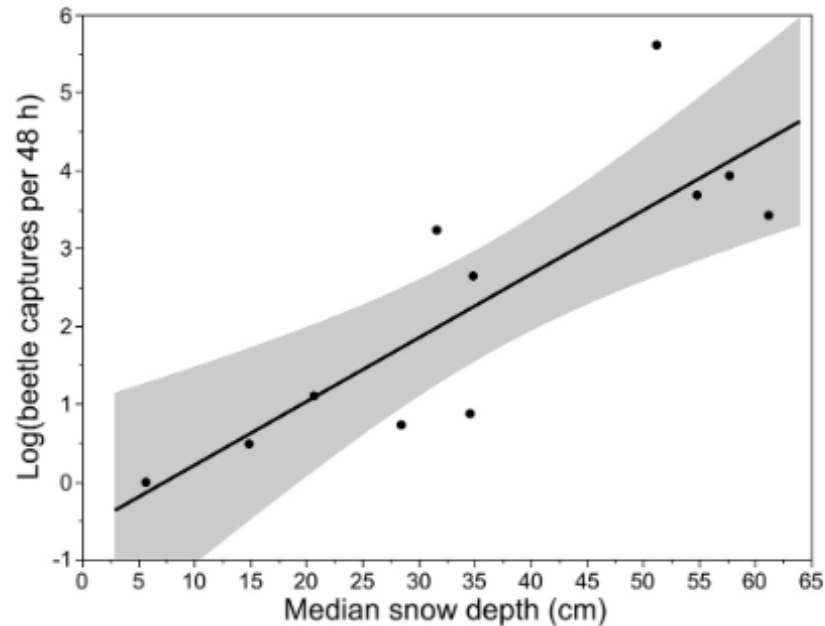
Window trap surveys 1970s
Replicated surveys 2015-2017

Harris *et al.* 2019

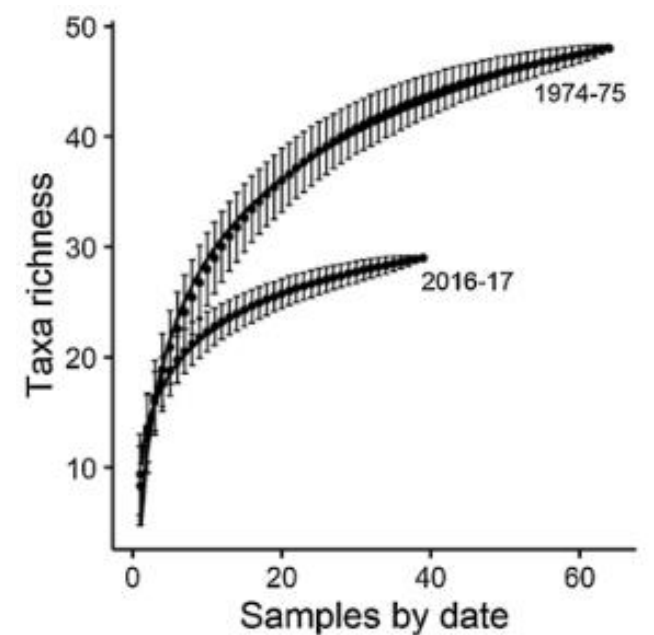
Decline in abundance



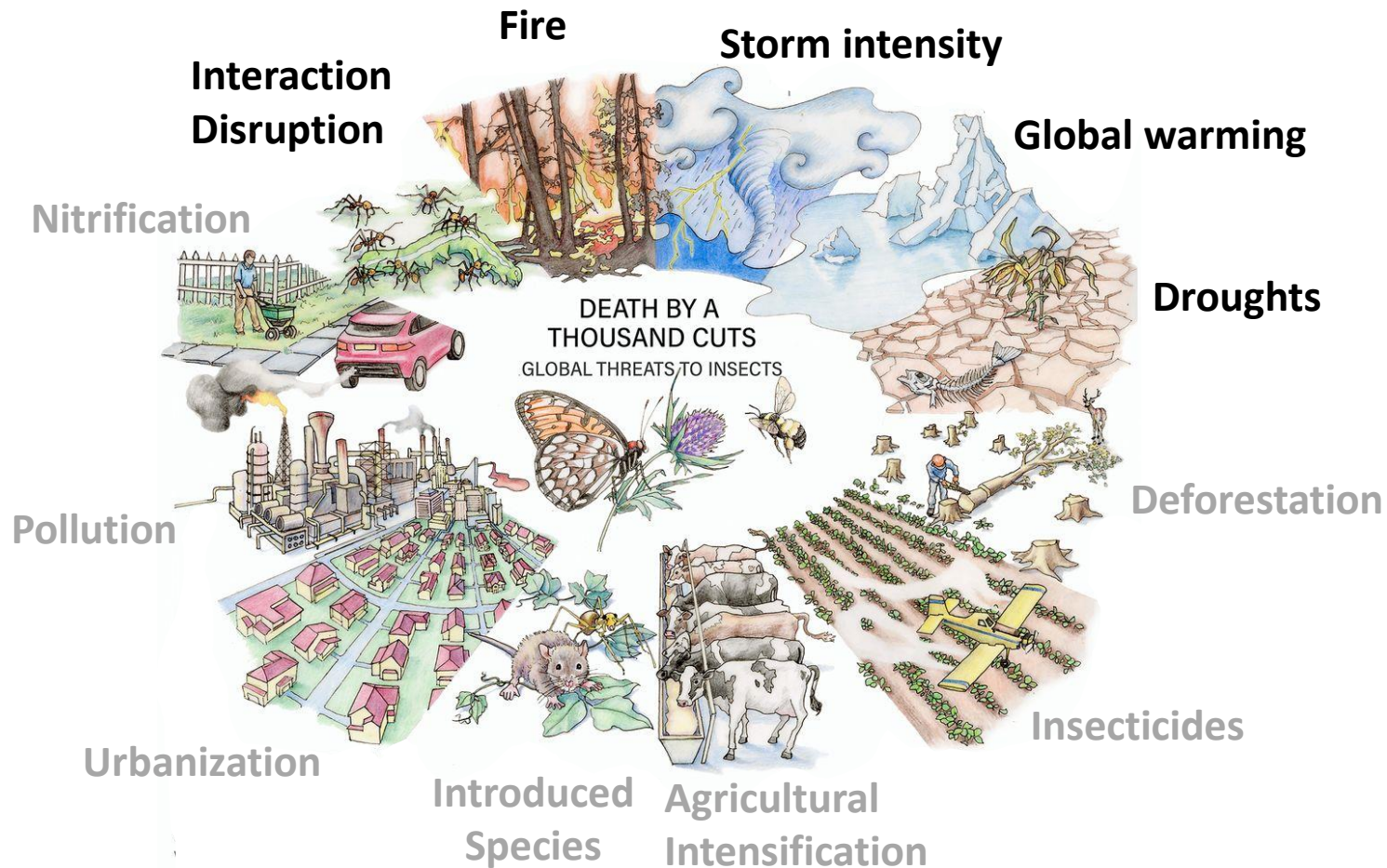
correlated with snow depth



Reduced species richness



What factors are contributing to observed declines?

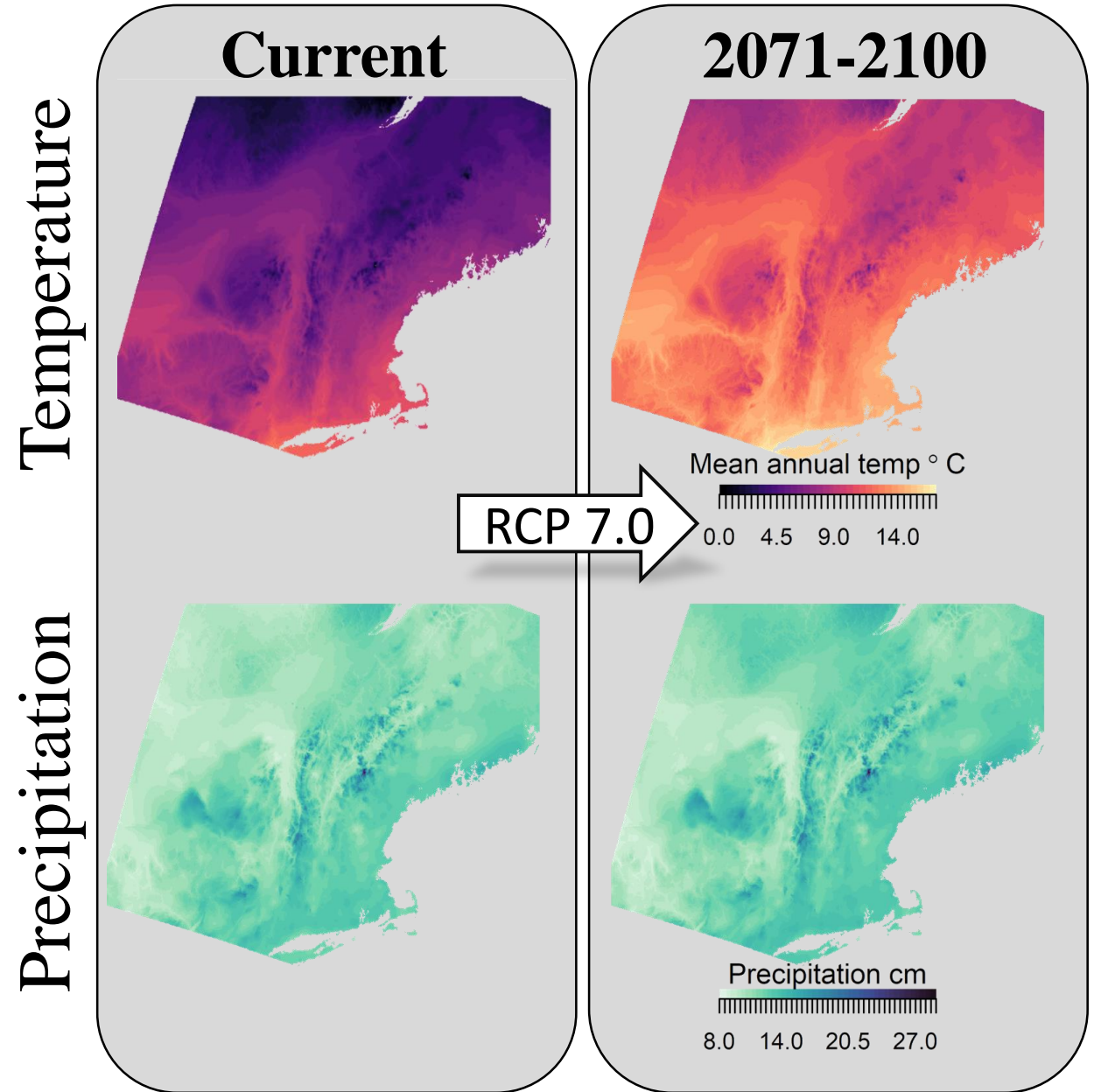


Climate change

Habitat conversion
Forest fragmentation
Pesticide use

Ways projected climate change could impact insect populations:

- 1) Reduce habitat suitability
- 2) Changing range limits
- 3) Alter timing of life-cycle



Importance of insects to forested ecosystems

Culturally important
& Aesthetics

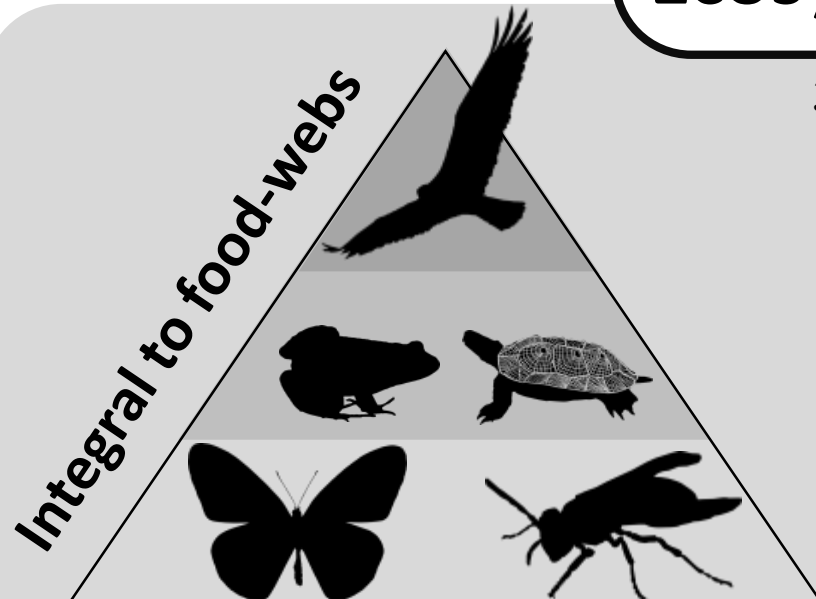


Pollination
Seed dispersal



Ecosystem services

350-570 caterpillars day⁻¹



Narango et al. 2017



Doug Tallamy

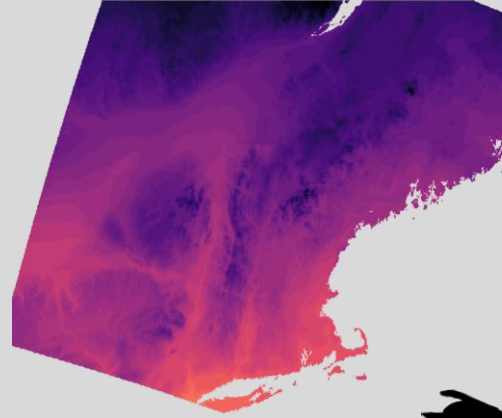
Bioindicators
Pest control
Soil aeration
many more



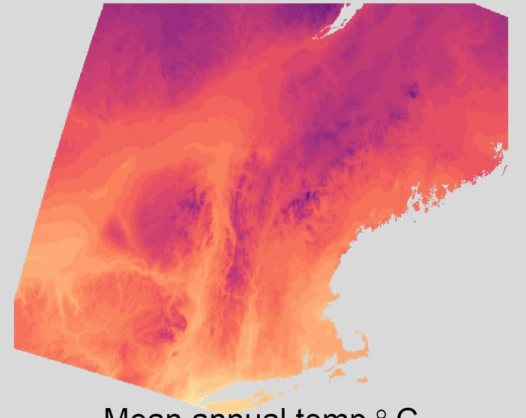
Since insects occur ubiquitously in food-webs, and serve as bioindicators of ecosystem health **understanding their response to climate change is drastically needed**

Temperature

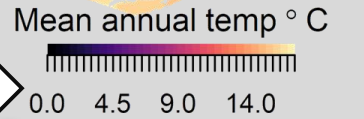
Current



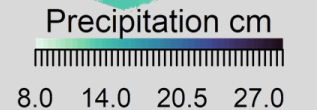
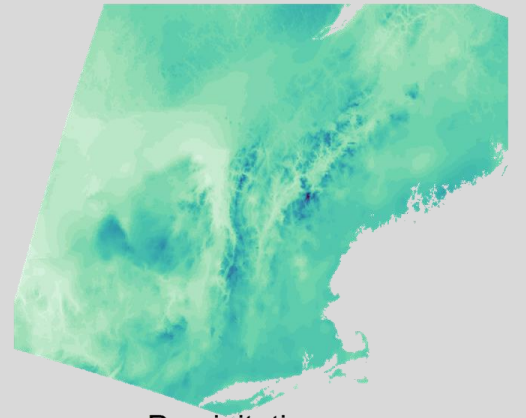
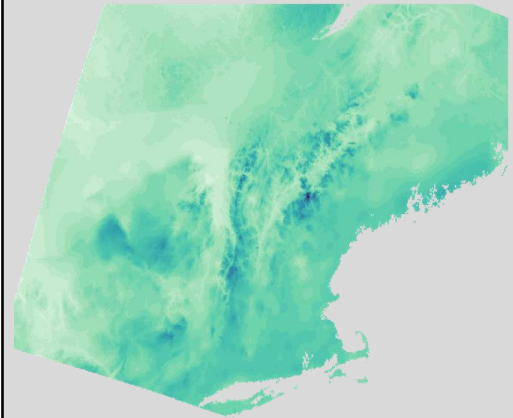
2071-2100



RCP 7.0



Precipitation



Objective: Develop species distribution models to identify current distributions and projected range expansion / shifts of forest insects given climate change

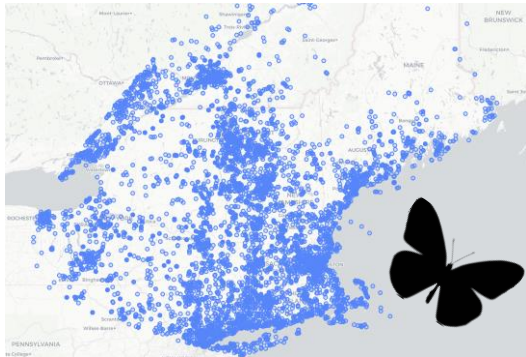
Justification:

- 1) Detailed distribution maps and habitat associations are lacking for most insects
needed to assess current and future risks
- 2) Current & future distribution maps address current data gaps and allow stakeholders to make informed management decisions given climate change

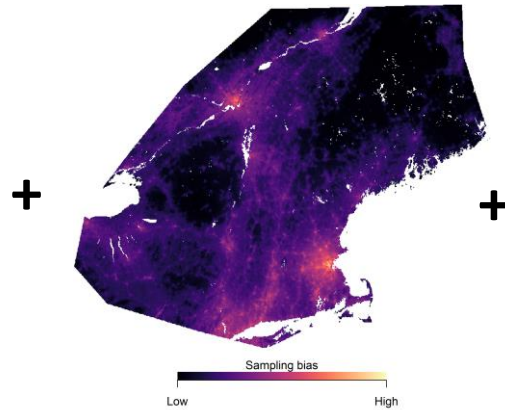


Modeling species distributions

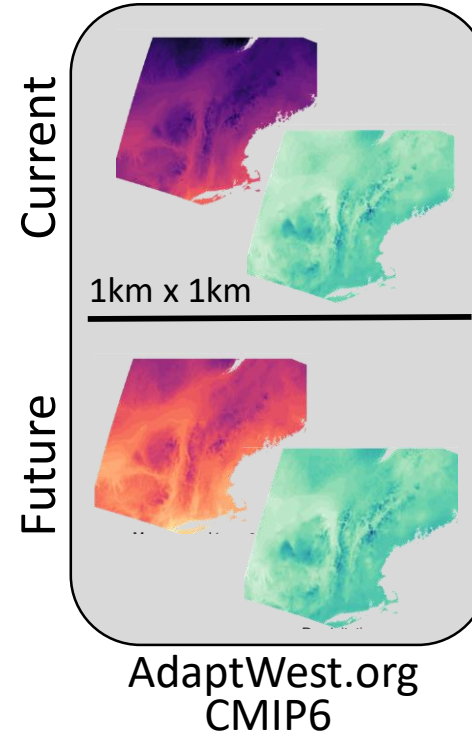
Presence data



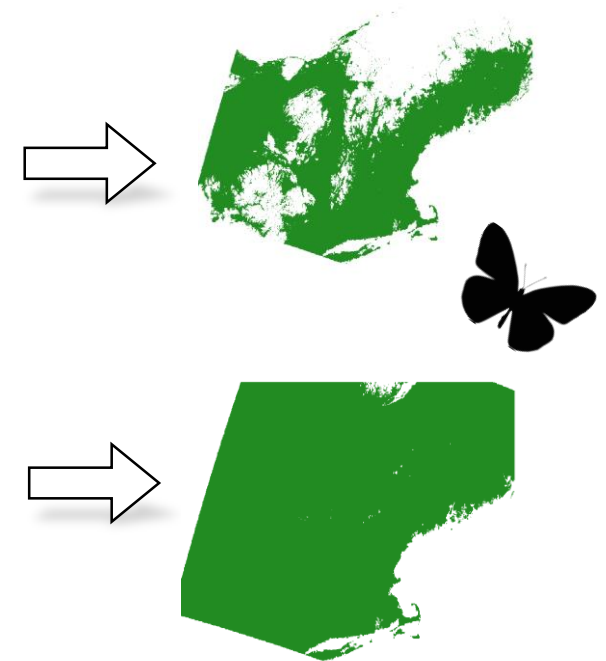
Sampling bias



Bioclimatic data



Distribution



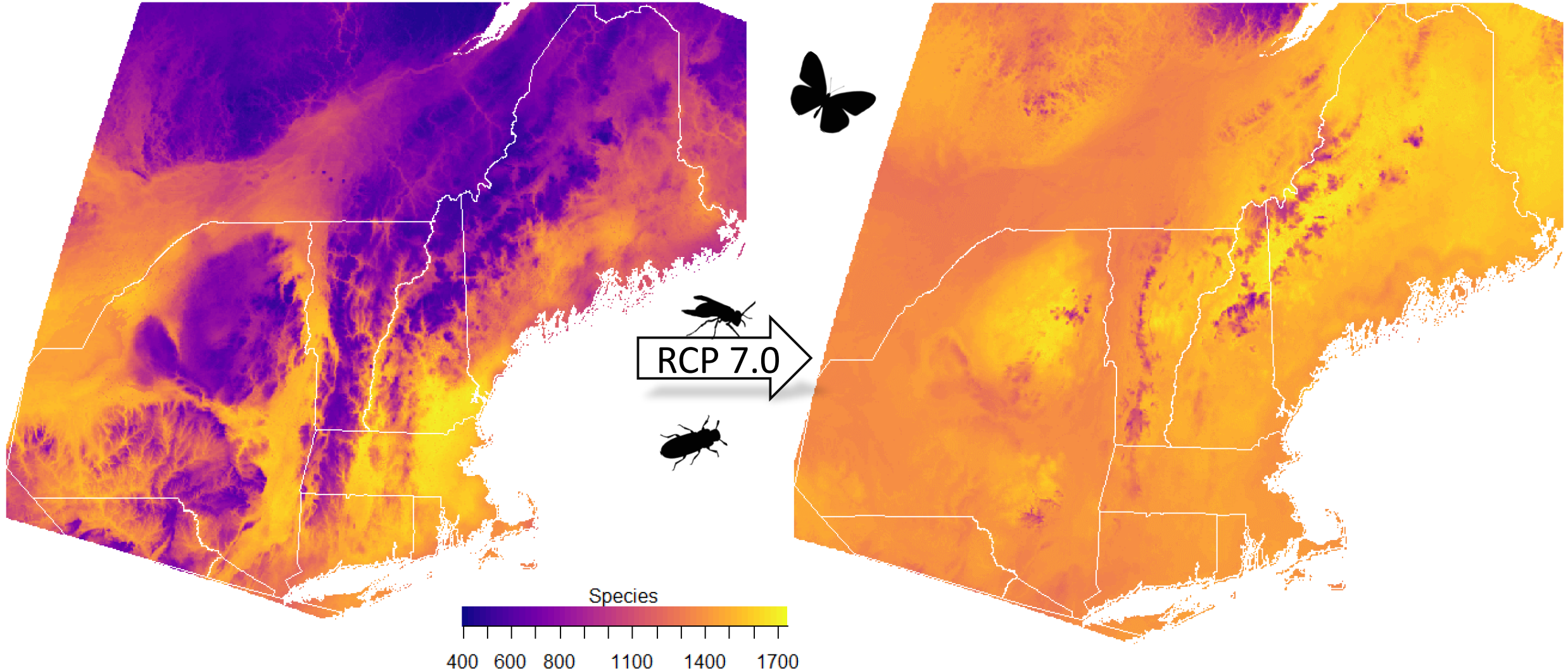
Where are forest insects across the northeast?

Current

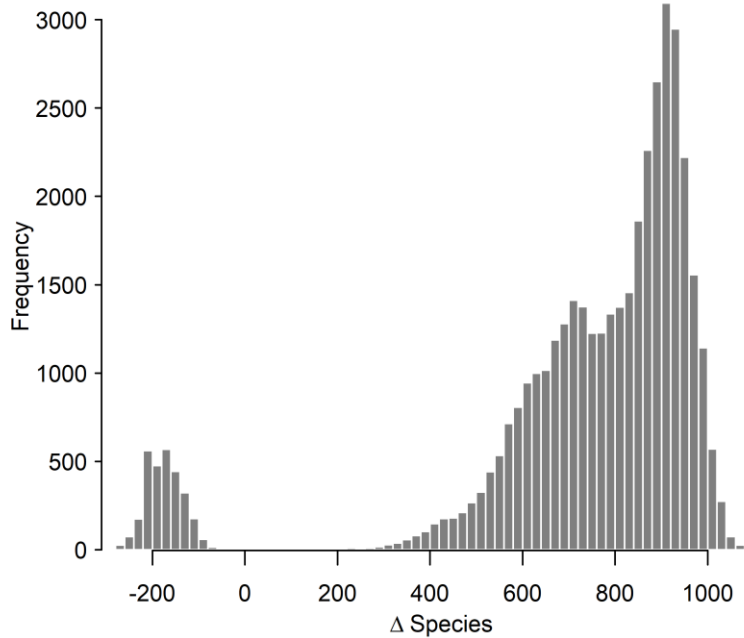
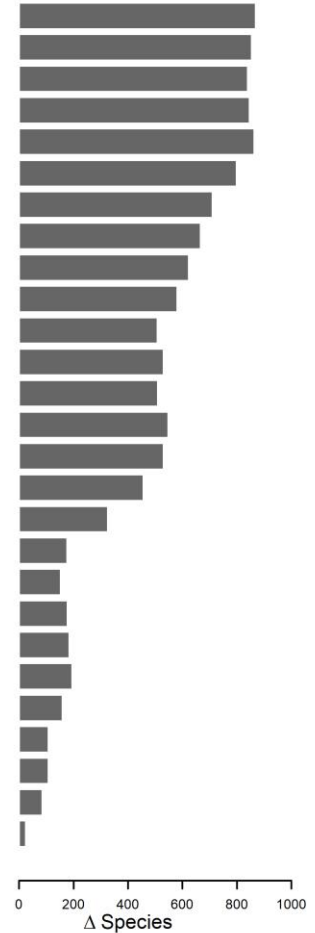
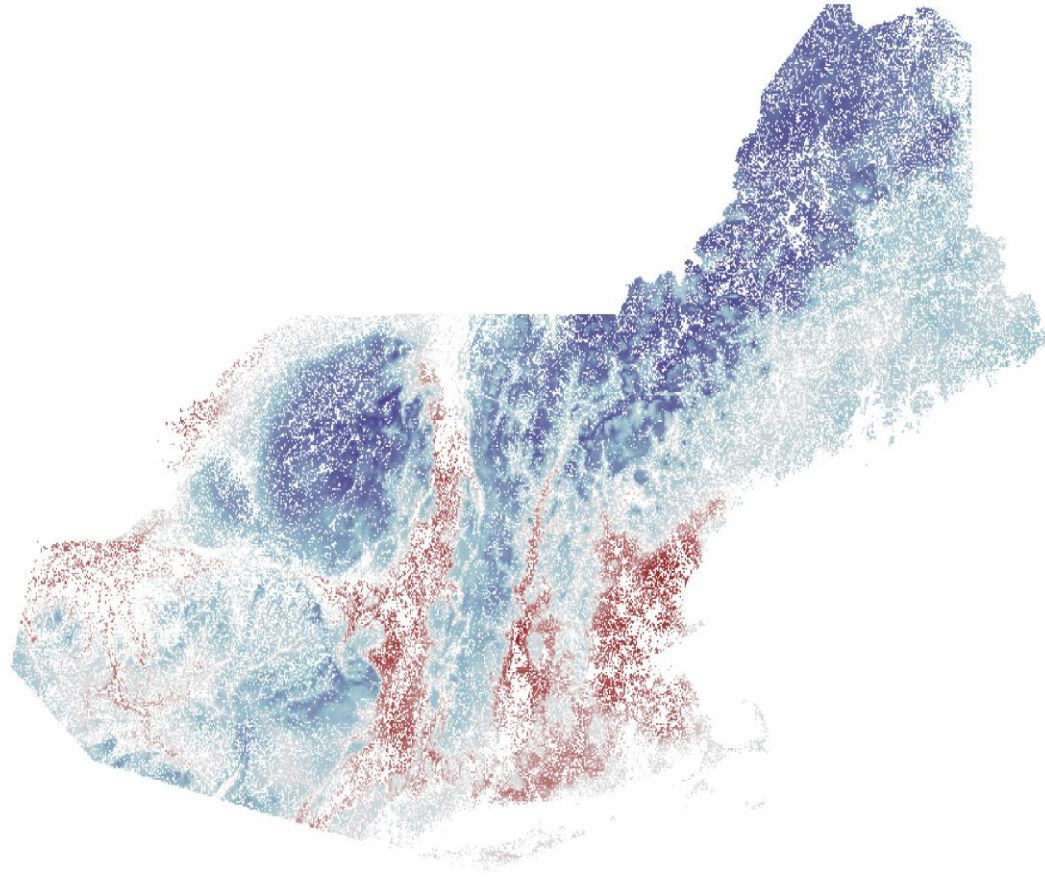
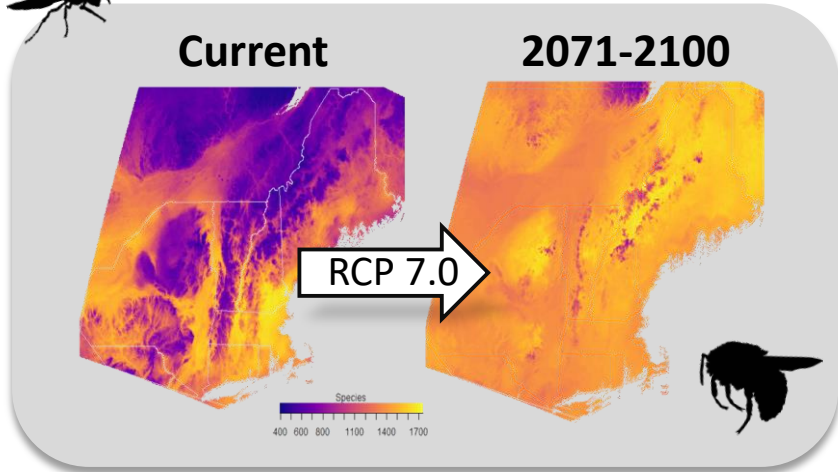
Range: 391 - 1738

2071-2100

Range: 658 - 1746



Where is insect richness likely to change the most?

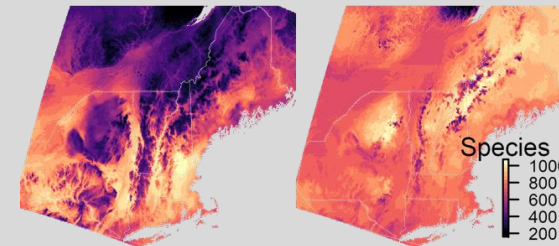


How will climate impact the major insect orders?

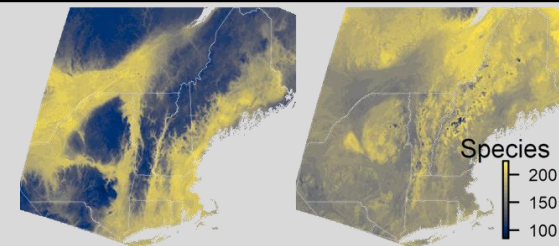
Current 2071-2100



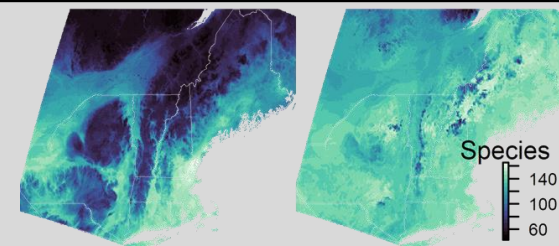
Lepidoptera



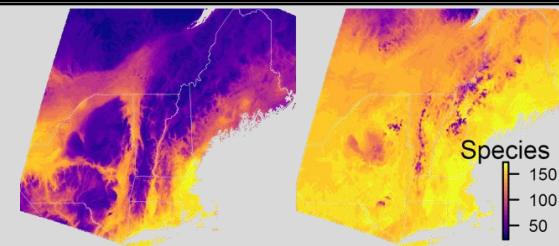
Coleoptera



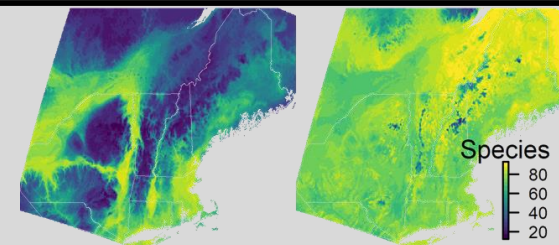
Diptera



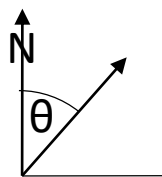
Hymenoptera



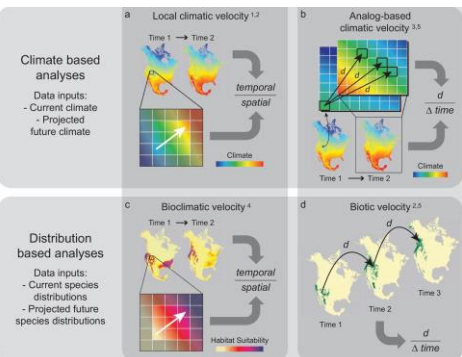
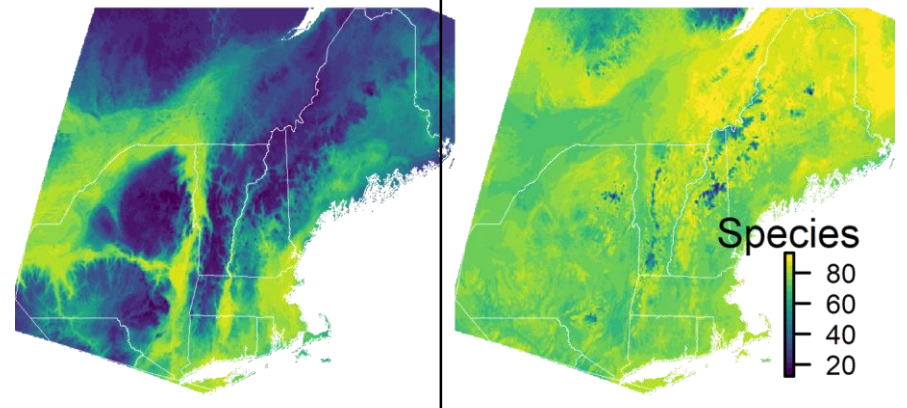
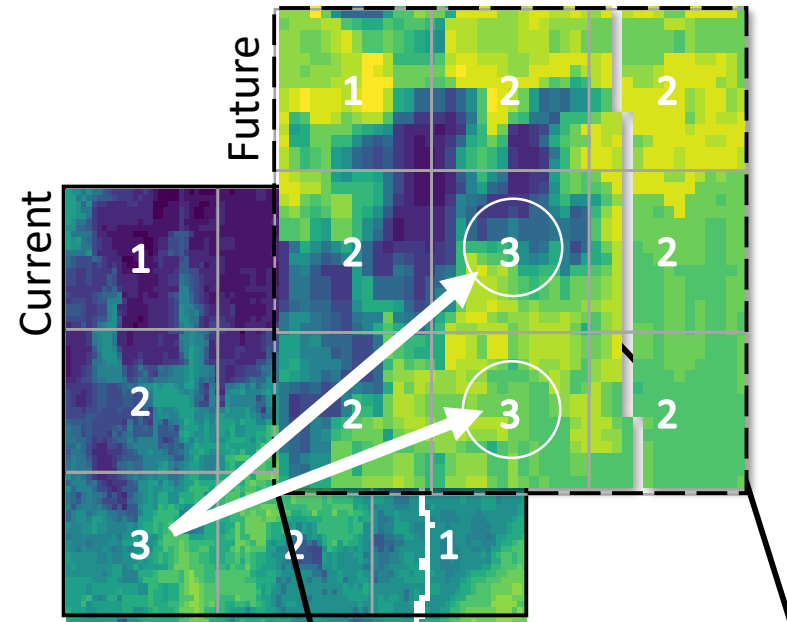
Hemiptera



$$\text{Velocity} = \frac{\text{distance}}{\Delta \text{time}}$$

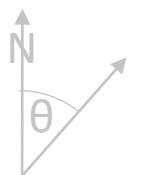
$$\text{Direction} = \theta$$


Species Richness Analog

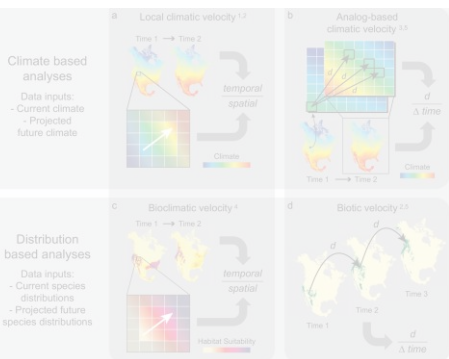
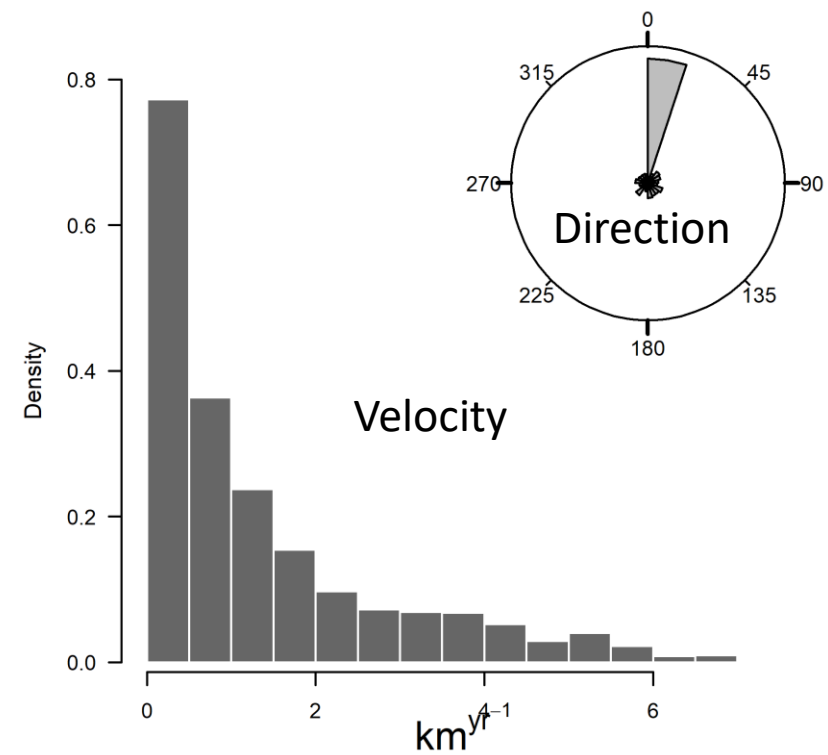
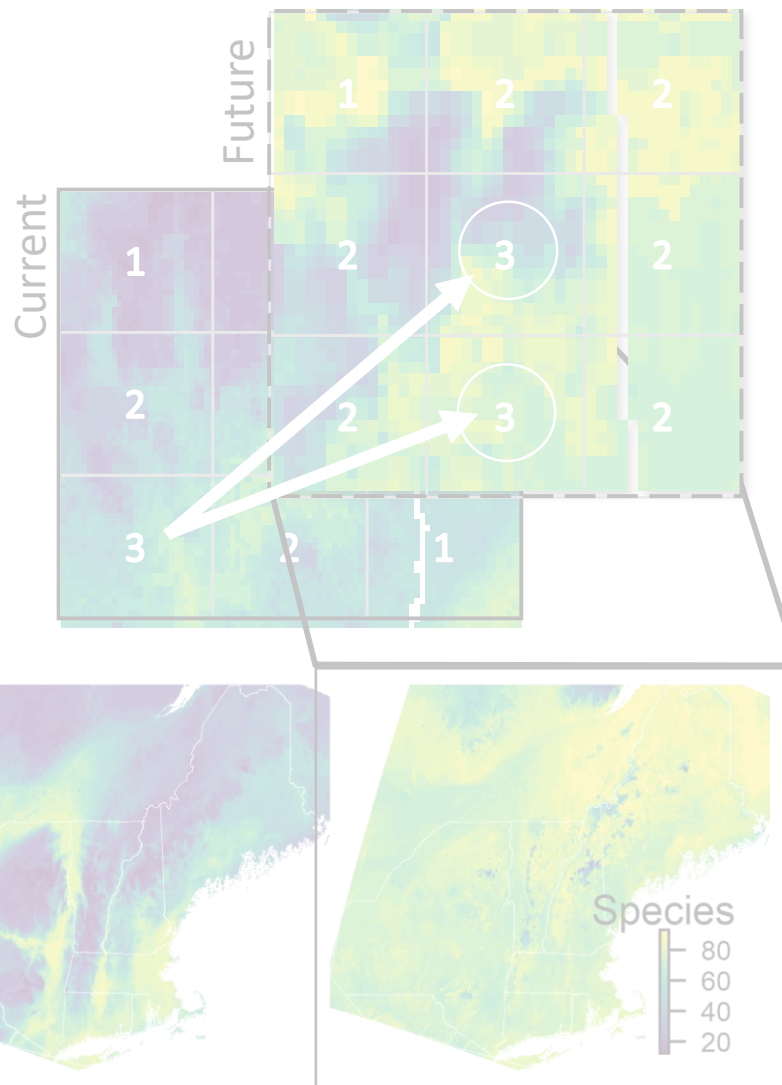


Carroll et al. 2015

$$\text{Velocity} = \frac{\text{distance}}{\Delta \text{time}}$$

$$\text{Direction} = \theta$$


Species Richness Analog



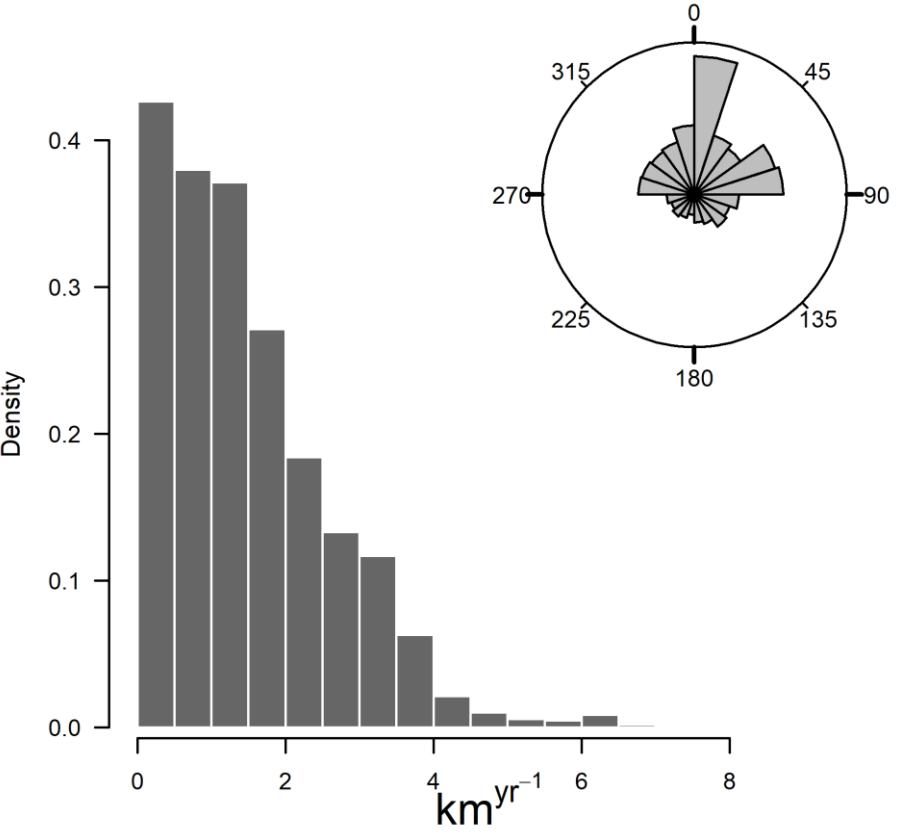
Carroll et al. 2015

How will climate impact the major insect orders?

Current 2071-2100

 **Lepidoptera**

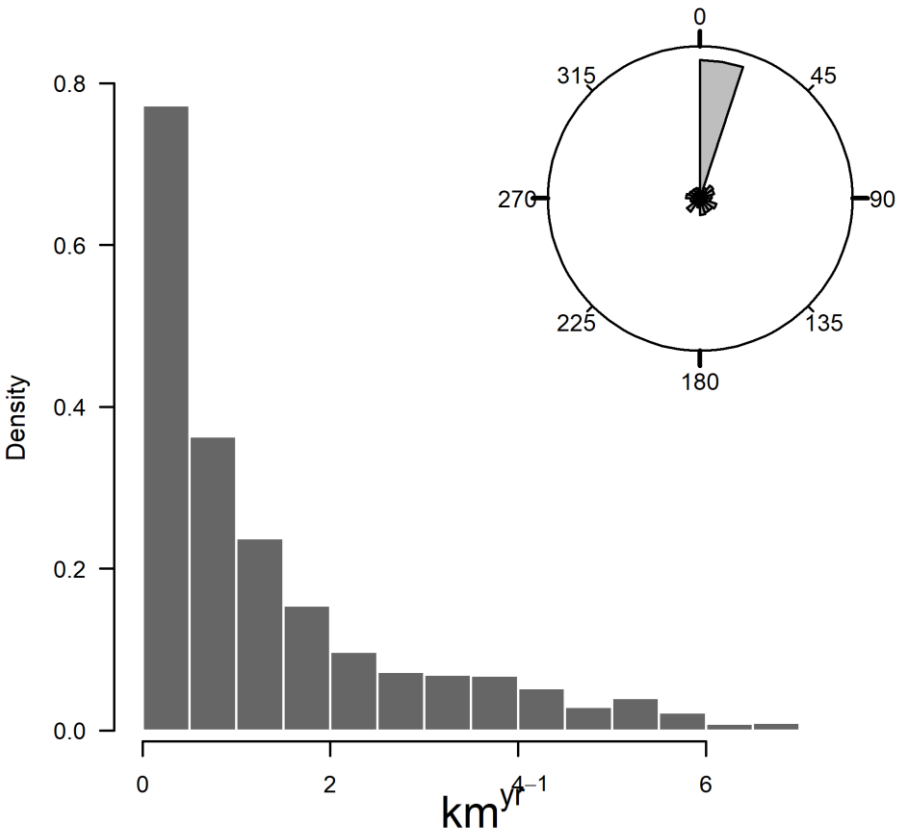




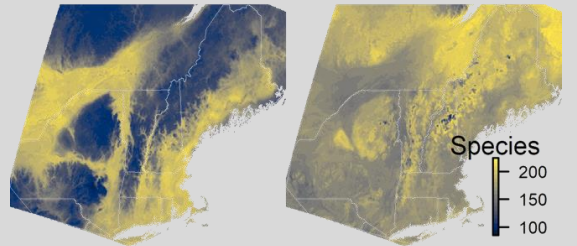
Four large, empty, rounded rectangular boxes stacked vertically, intended for notes or additional information.

How will climate impact the major insect orders?

Current 2071-2100

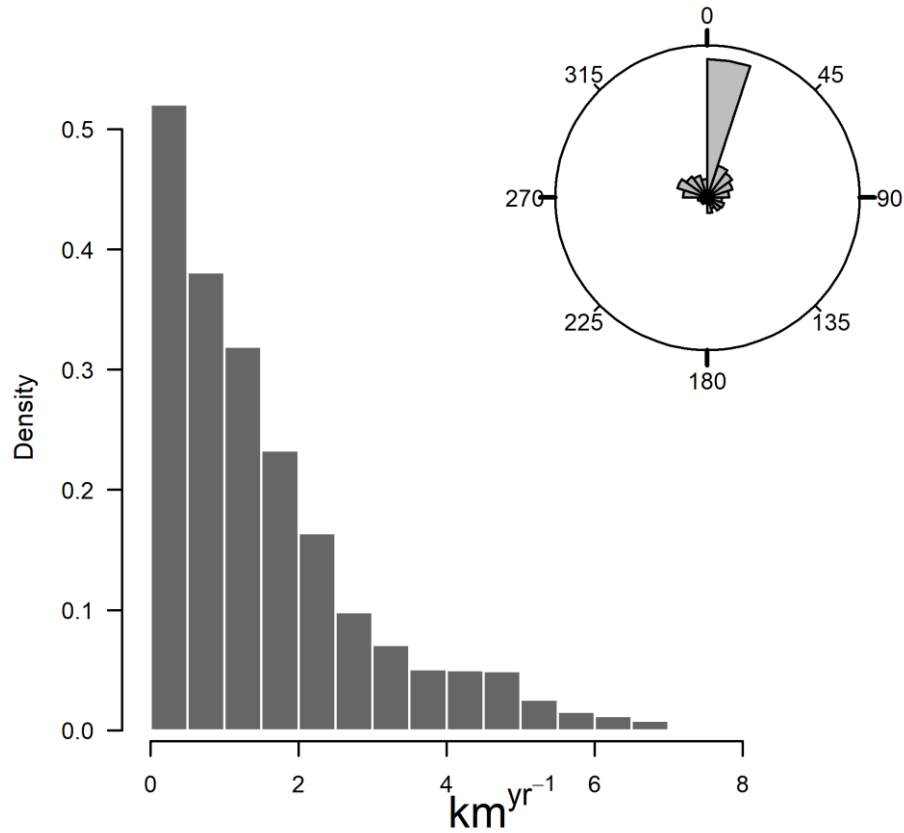


Coleoptera

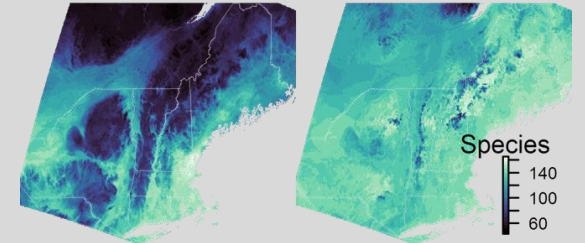


How will climate impact the major insect orders?

Current 2071-2100

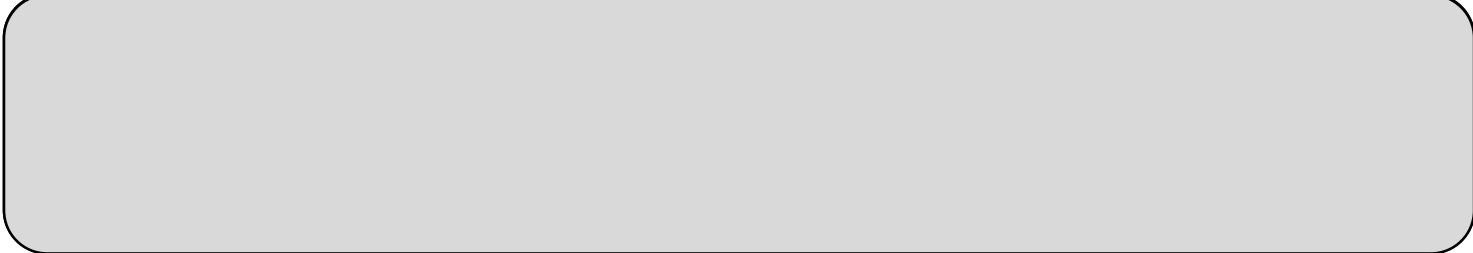
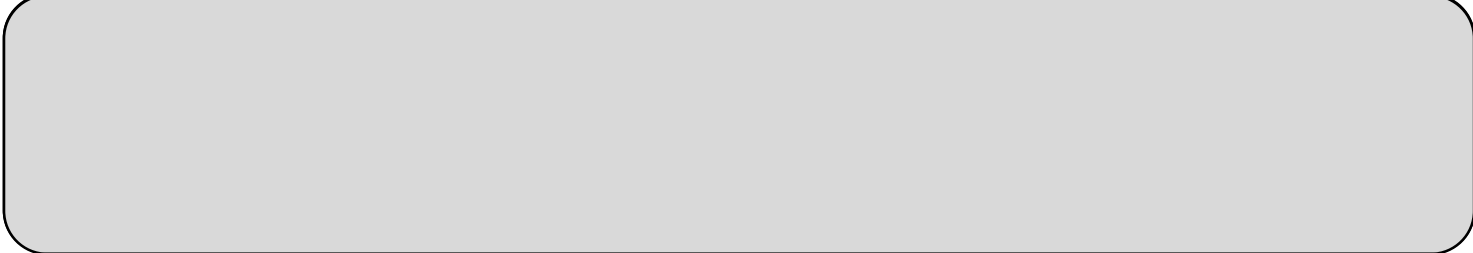
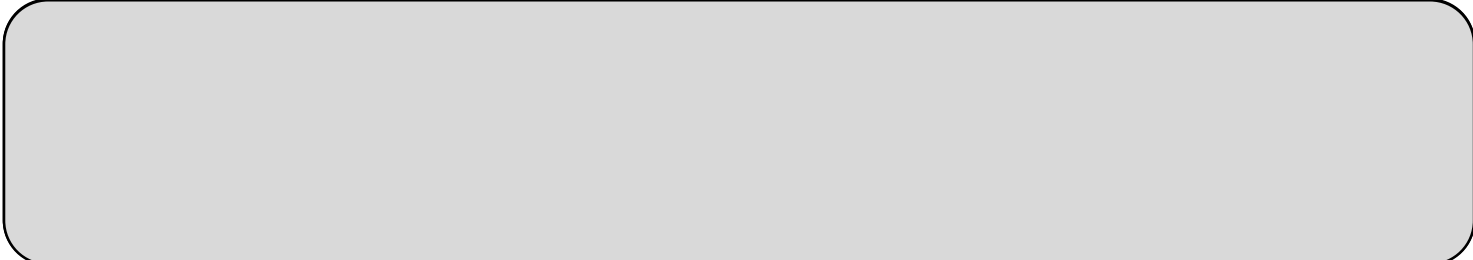
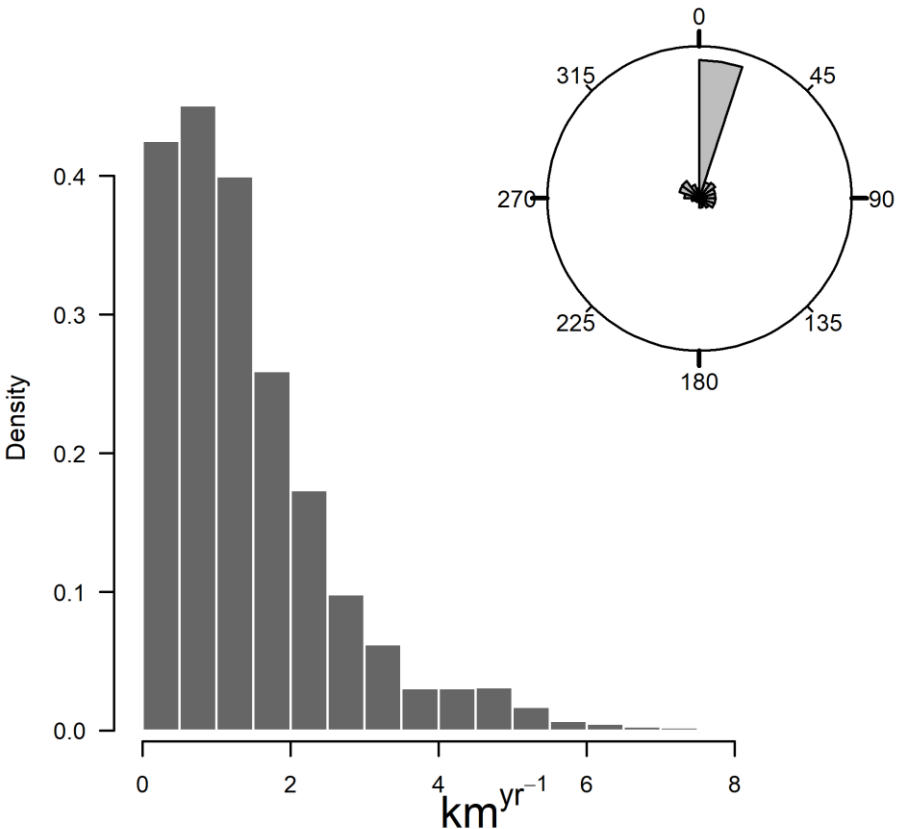


Diptera



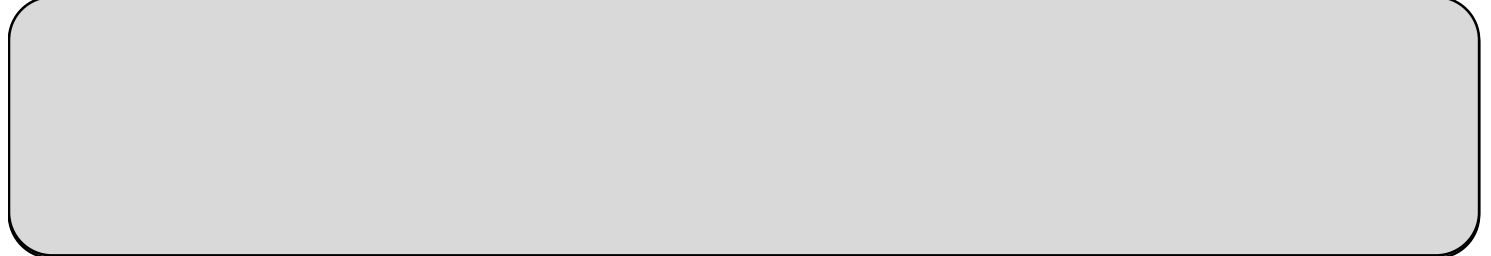
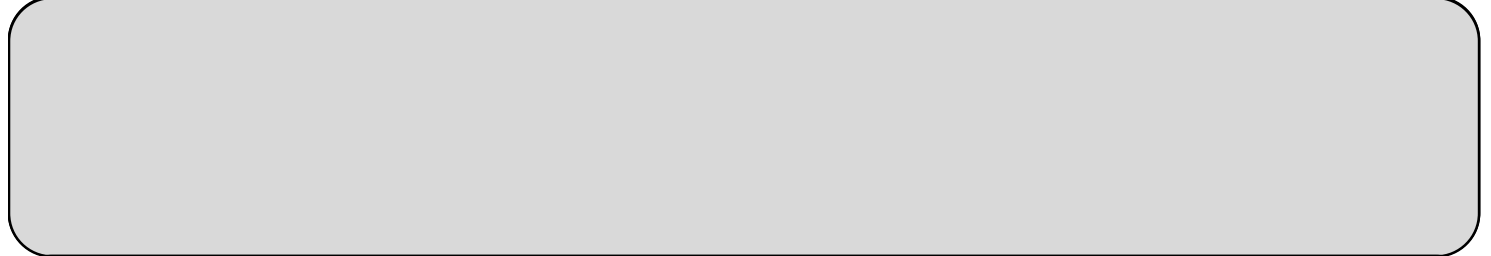
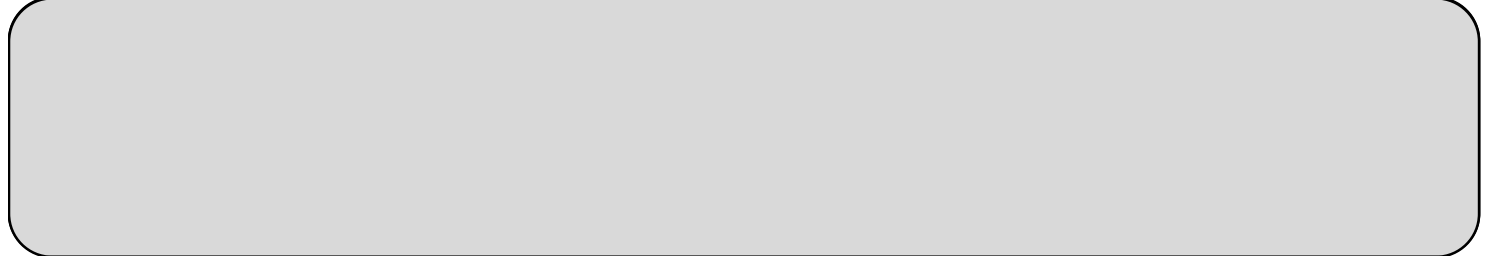
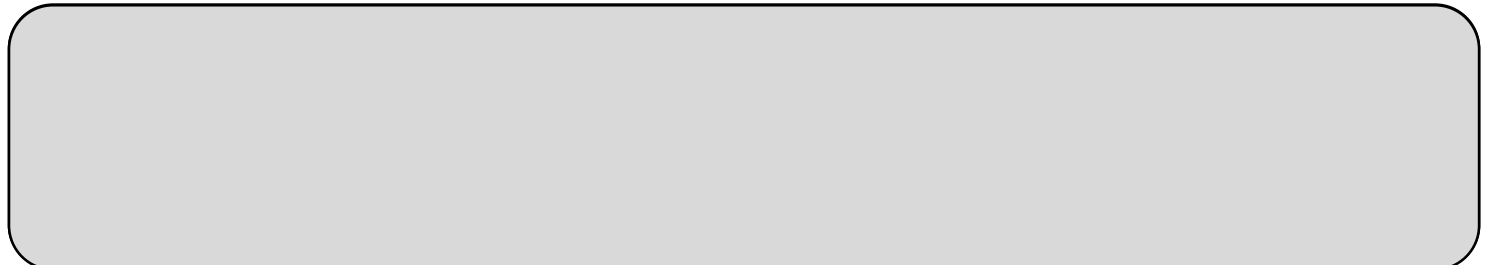
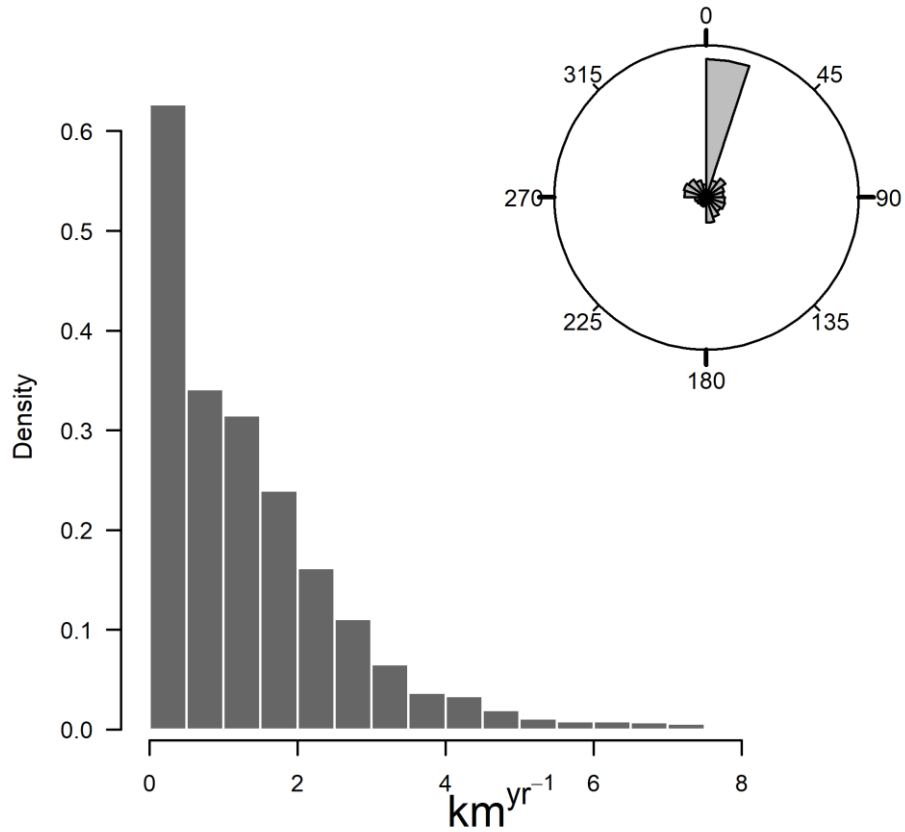
How will climate impact the major insect orders?

Current 2071-2100

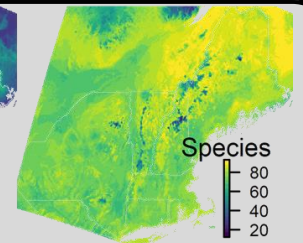
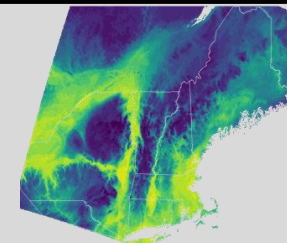


How will climate impact the major insect orders?

Current 2071-2100

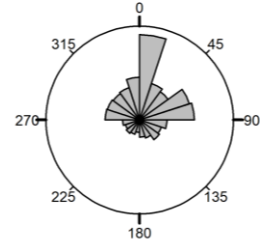


Hemiptera

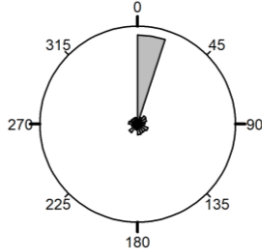
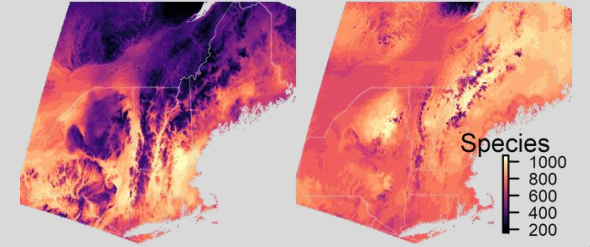


Current 2071-2100

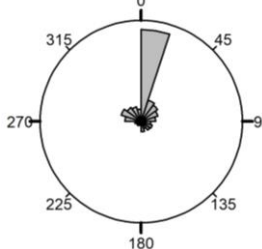
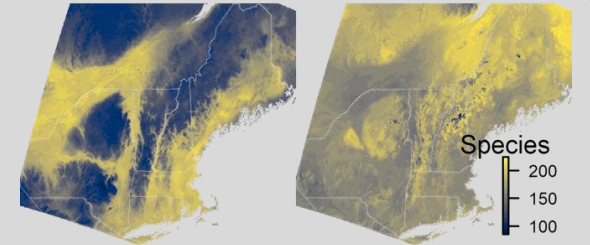
All orders
moving
Northward



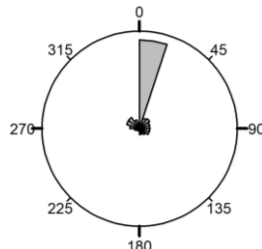
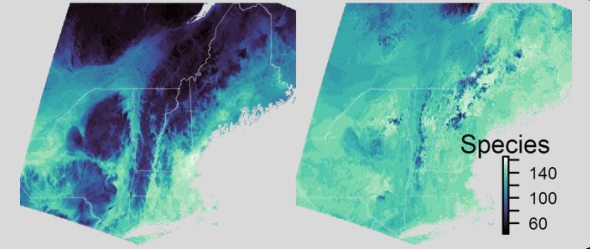
Lepidoptera



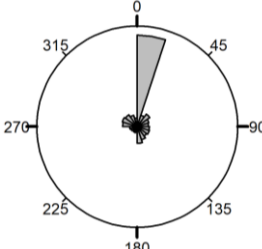
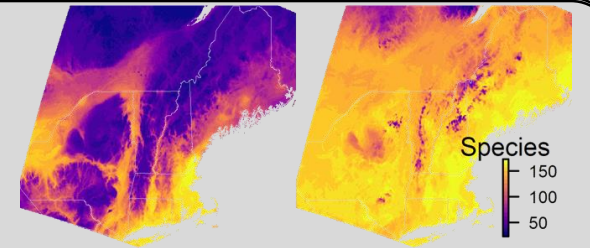
Coleoptera



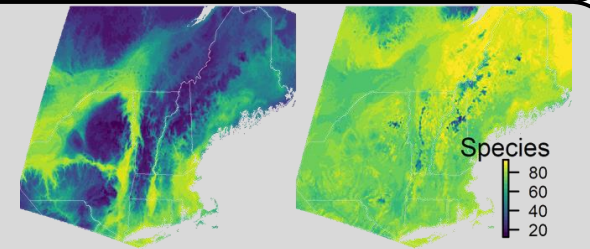
Diptera



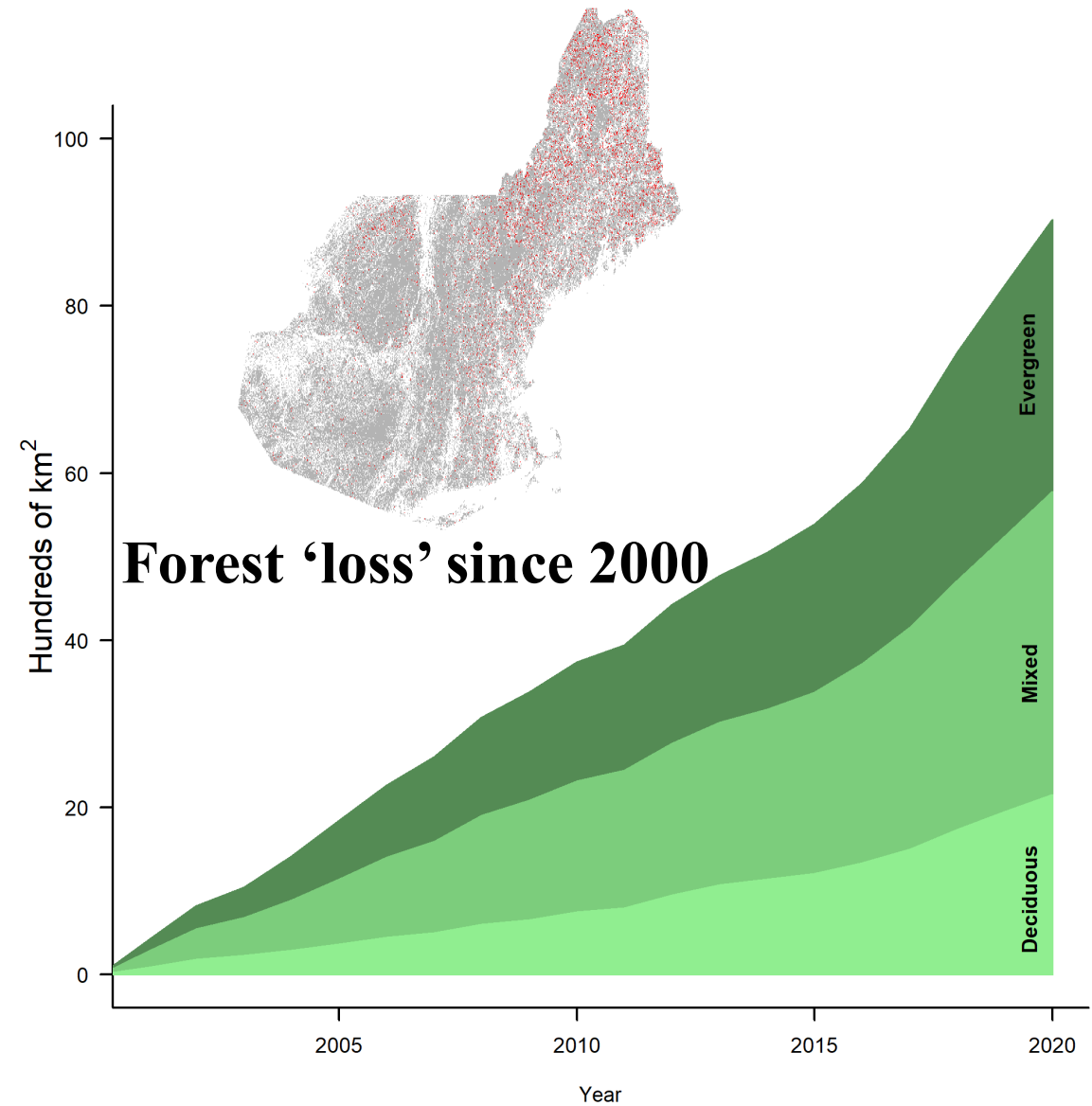
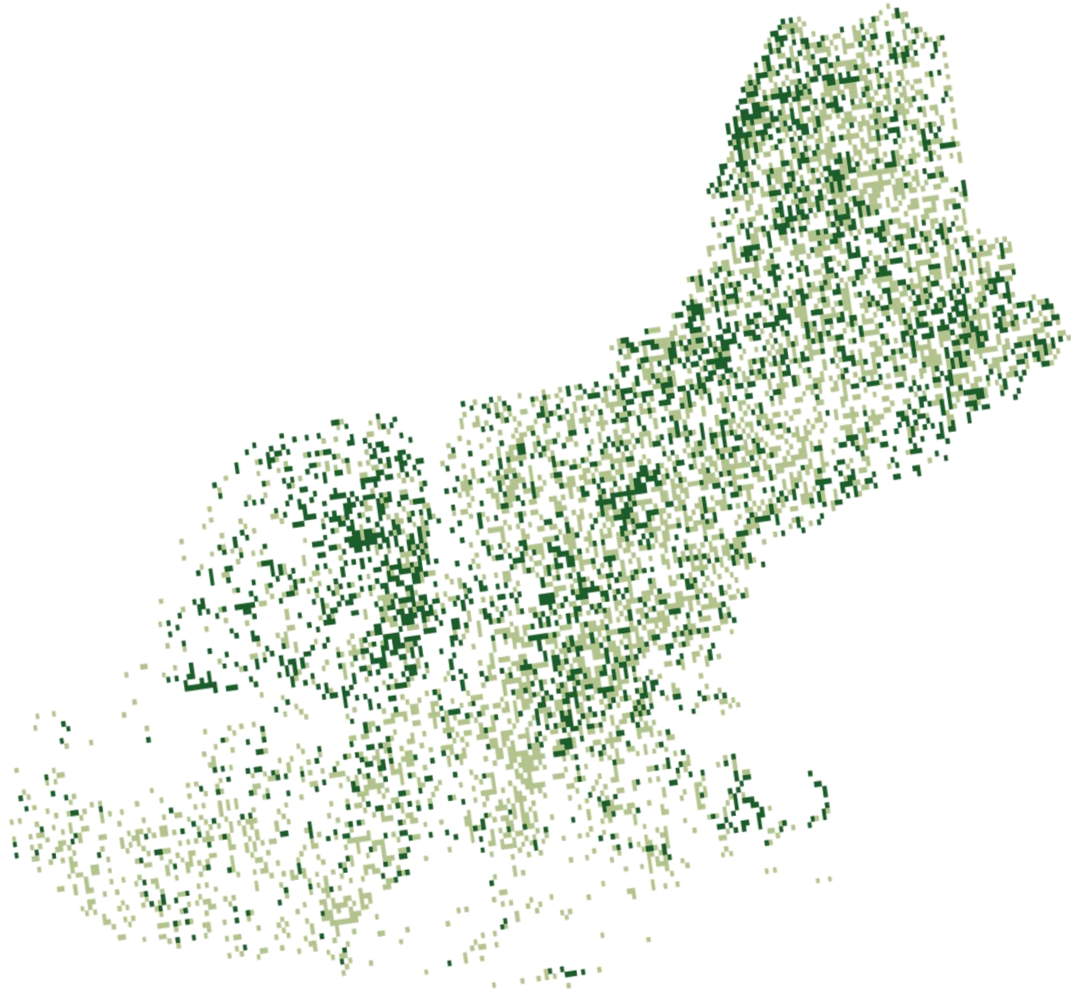
Hymenoptera



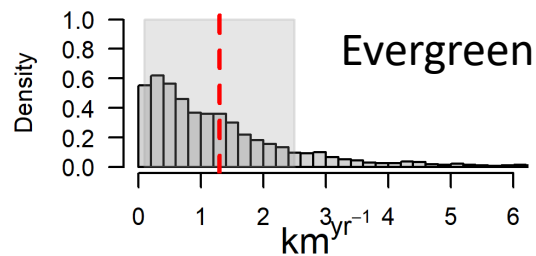
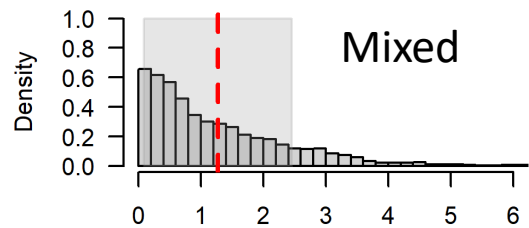
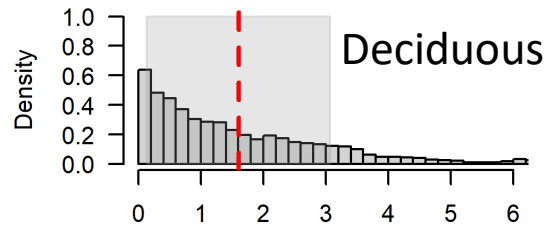
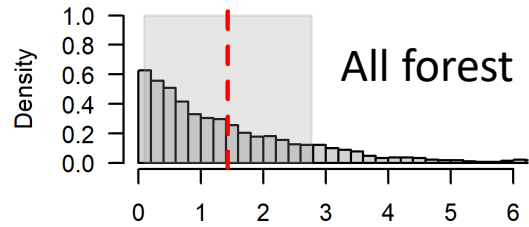
Hemiptera



Does velocity differ by forest type?



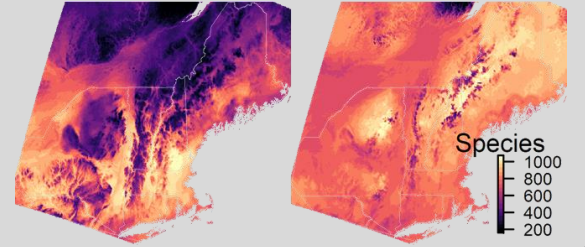
Velocity by forest type



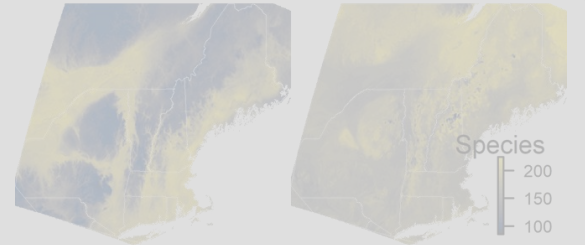
Current 2071-2100



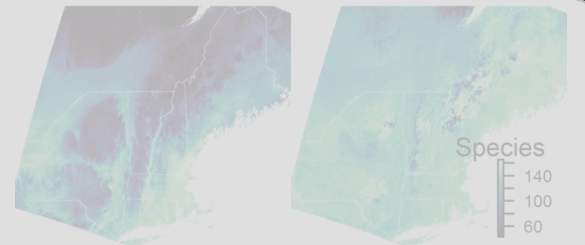
Lepidoptera



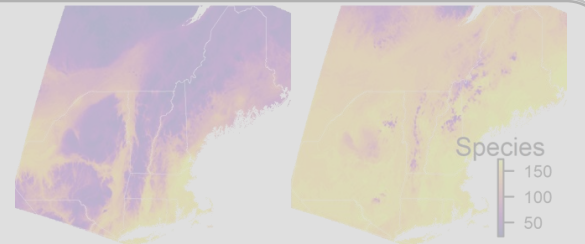
Coleoptera



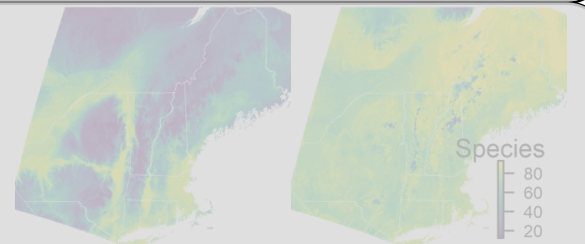
Diptera



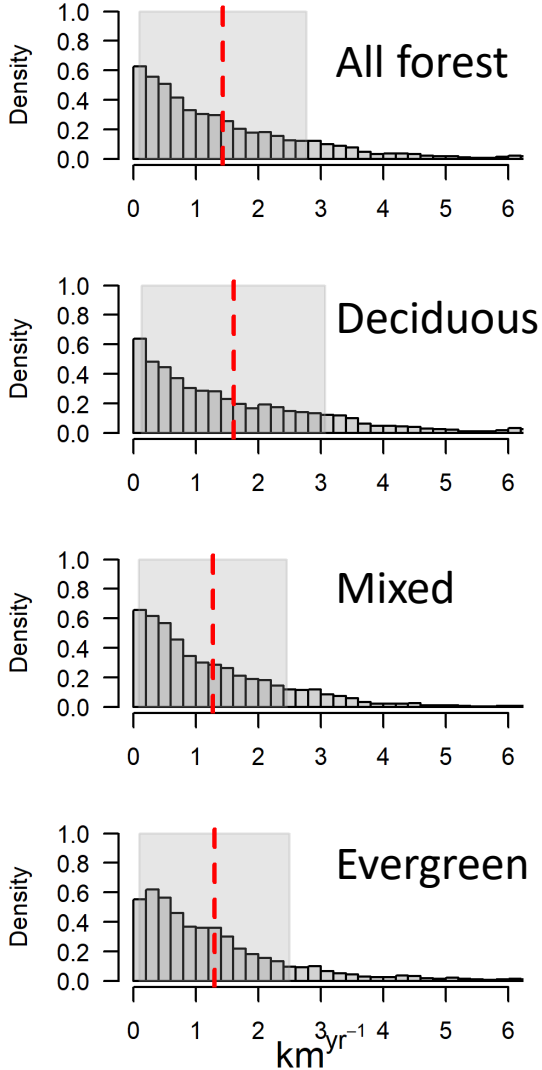
Hymenoptera



Hemiptera



Velocity by forest type



Lepidoptera

Coleoptera

Hymenoptera

Hemiptera

The major orders show similar velocity patterns within forest types

Species

1000
800
600
400
200

Species

200
150
100

Species

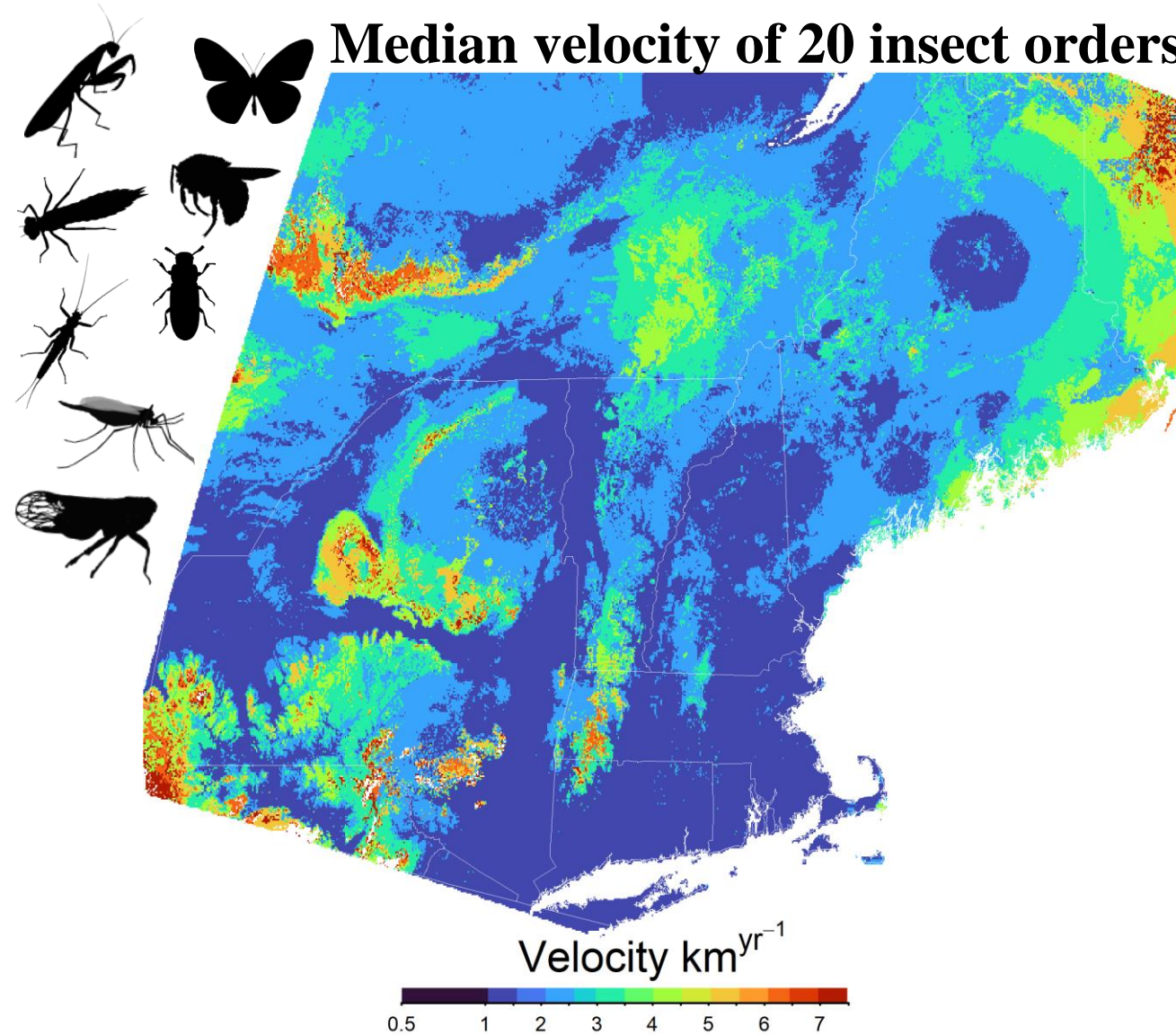
150
100
50

Species

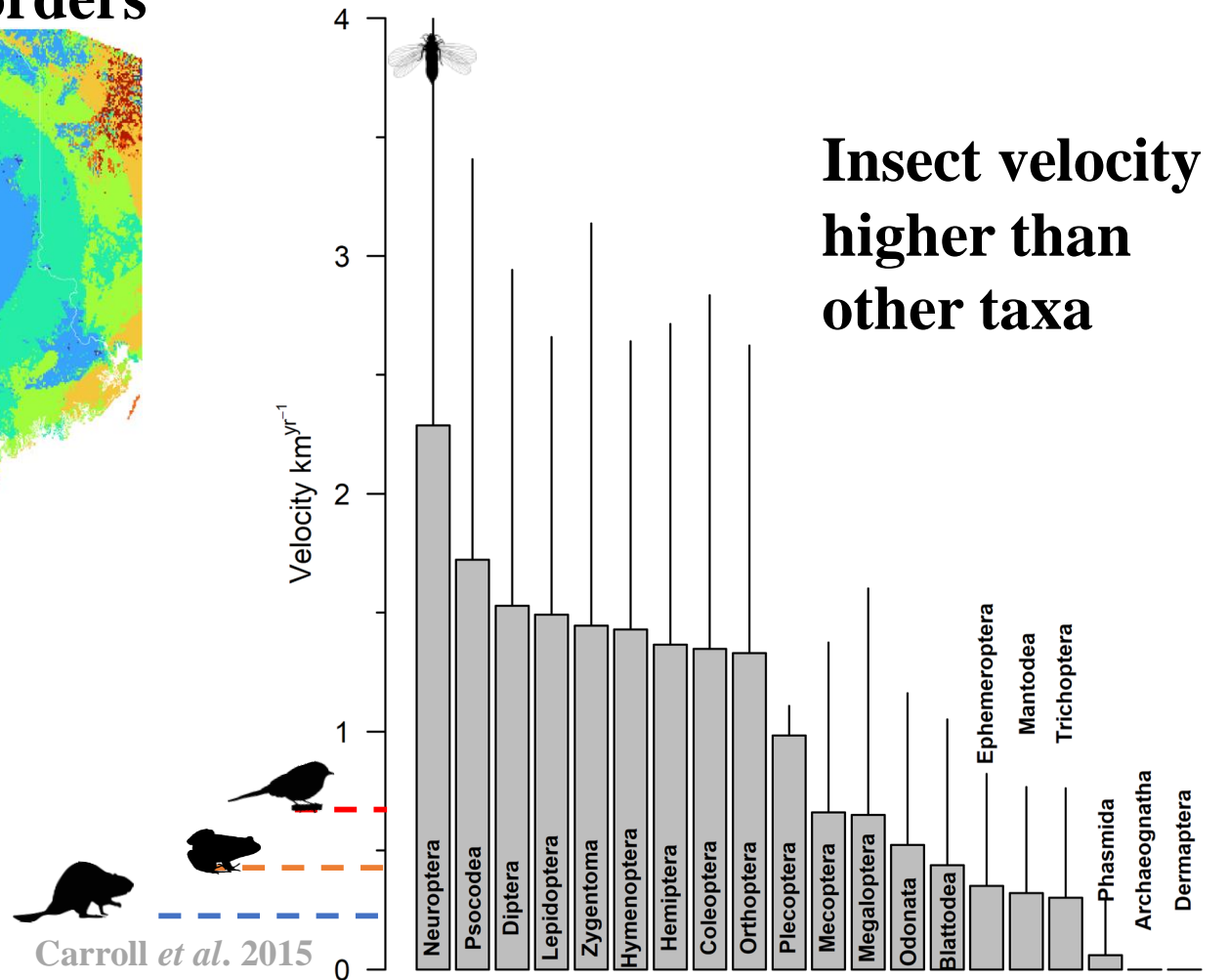
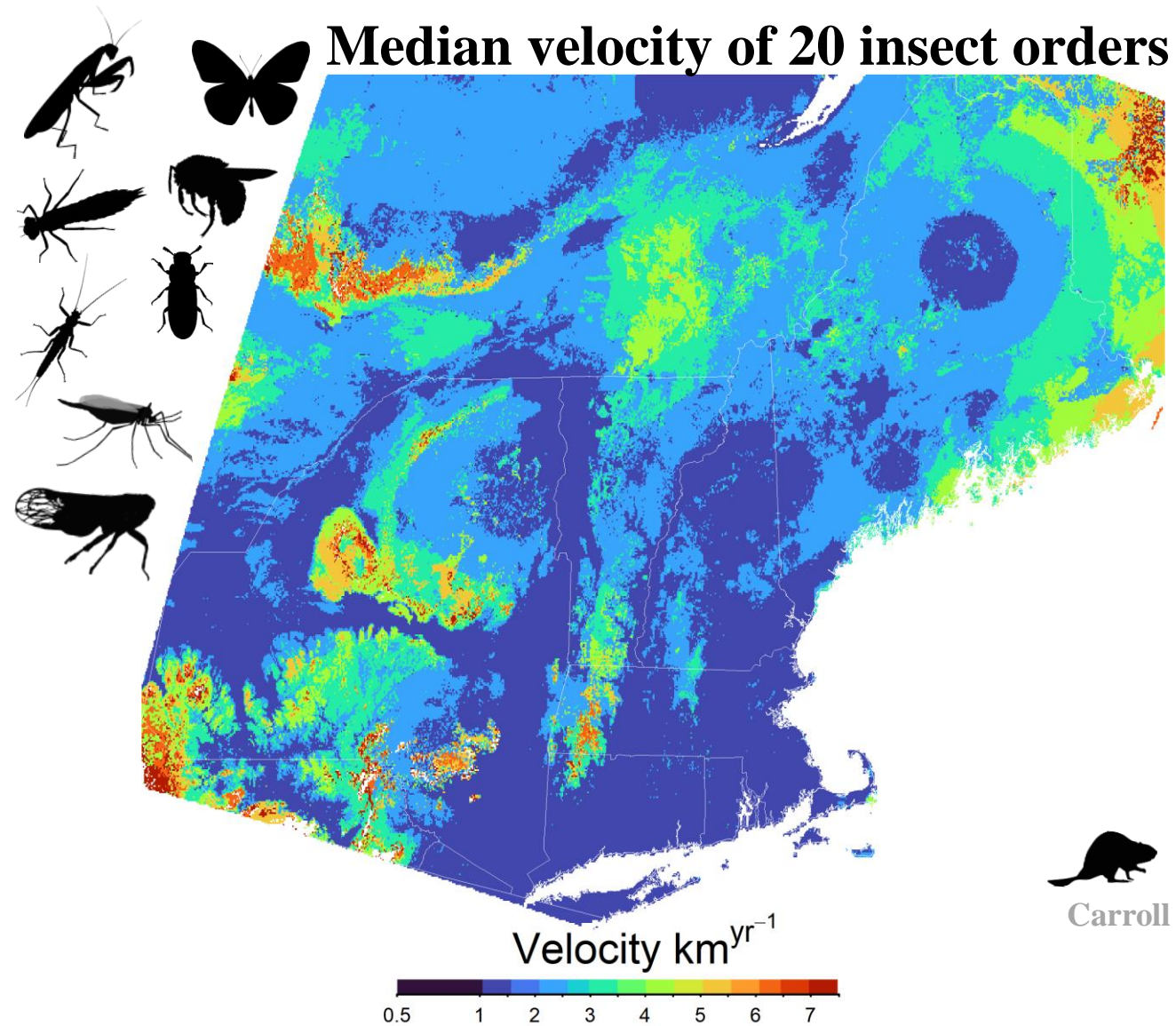
80
60
40
20

Insect velocity across New England is high!

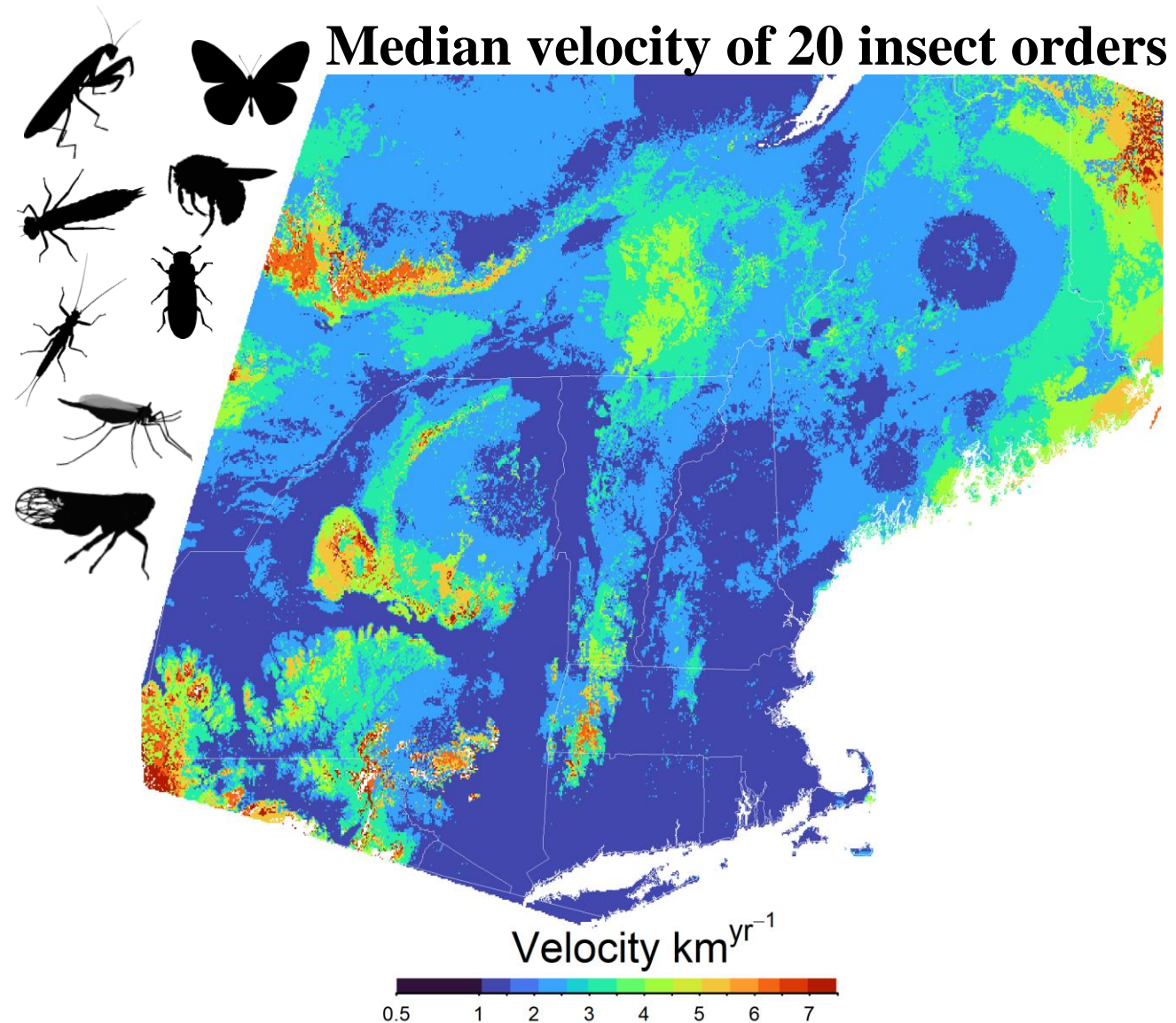
Median velocity of 20 insect orders






Insect velocity across New England is high!

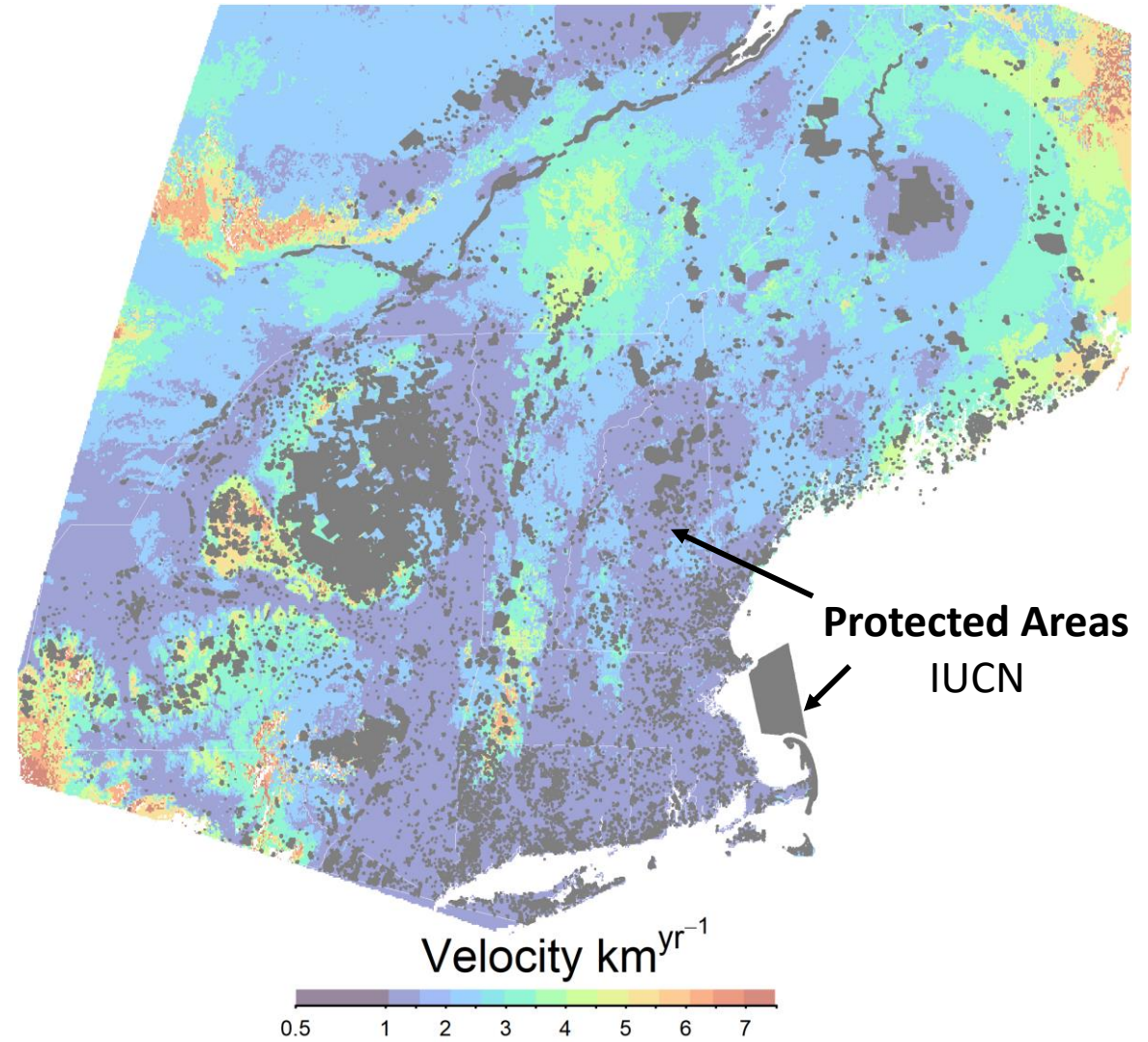
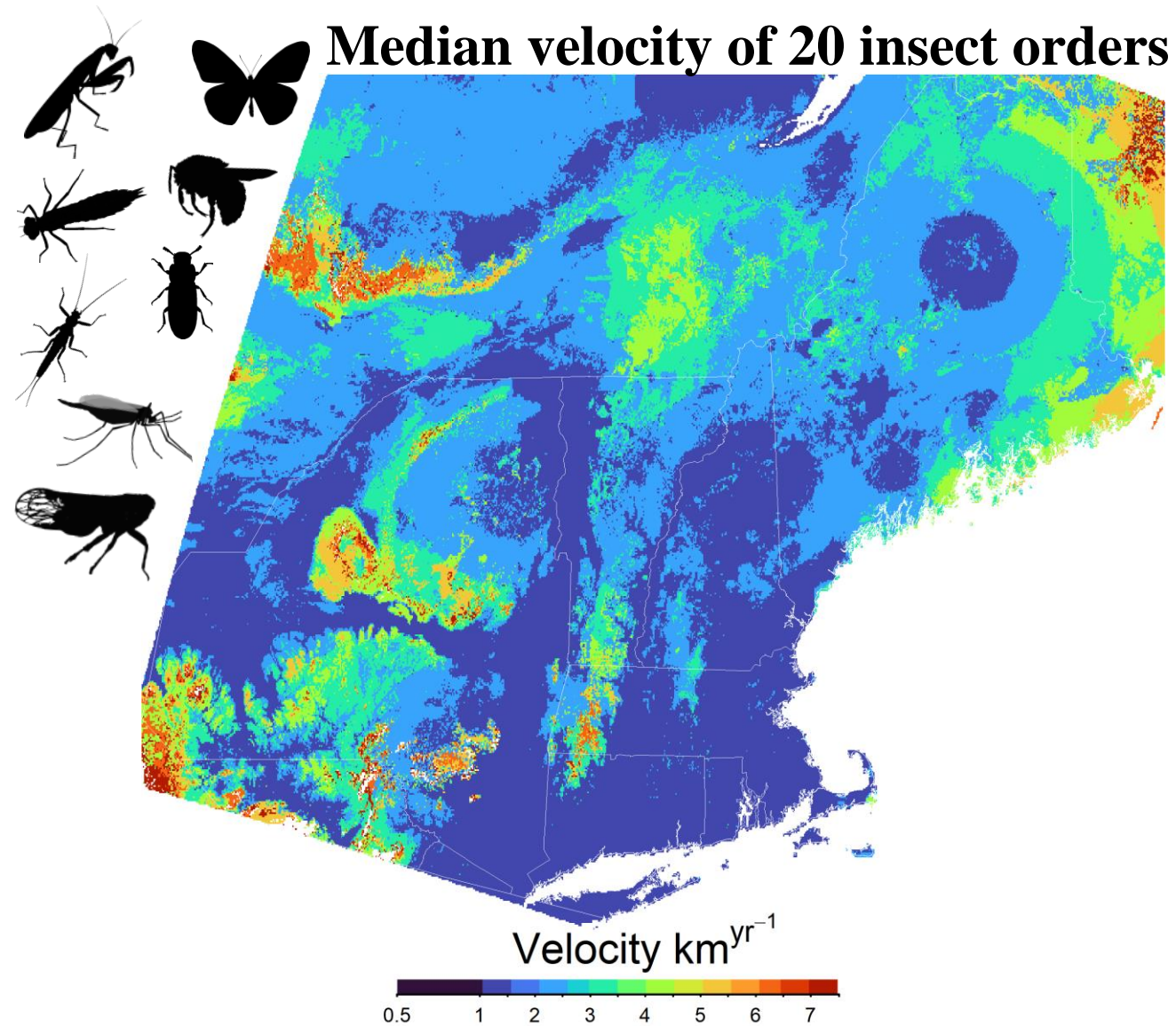


Insect life-histories are linked to temperature & climate



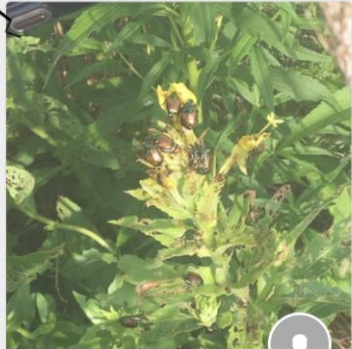
- 1) Development 
- 2) Phenology 
- 3) Migrations 
- 4) Number of generations

Identifying areas to focus future conservation efforts



Community scientist observations make this work possible

Thank you for being curious!



Japanese Beetle

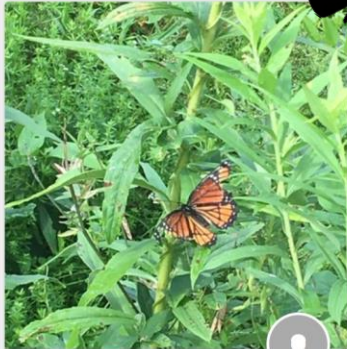
(*Popillia japonica*)

Research Grade



1

3mo



Viceroy

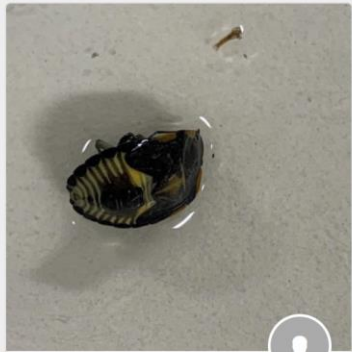
(*Limenitis archippus*)

Research Grade



2

3mo



Green Stink Bug

(*Chinavia hilaris*)

Research Grade



2

2mo



Monarch

(*Danaus plexippus*)

Research Grade



1

3mo

Vermont Atlas of Life

Discovering and Sharing Biodiversity



Add Observations

View Species

Stats

Totals

765200

Observations »

10407

Species »

17013

People »



Most Observations

erikamitchell
85548 observations

charlie
40058 observations

susanelliott
20615 observations

larry522
11533 observations

joshualincoln
10825 observations

Most Species

erikamitchell
3524 species

susanelliott
2494 species

larry522
2464 species

charlie
1951 species

joannerusso
1944 species

Most Observed Species

Black-capped Chickadee
4318 observations

American Robin
4001 observations

White-tailed Deer
3750 observations

Monarch
3725 observations

Eastern Newt
3499 observations

The Vermont Atlas of Life

Uniting People and Biodiversity Data for Conservation



Vermont Center for Ecostudies advances conservation of wildlife across the Americas through research, monitoring, and community engagement. We deliver the science people need to make good decisions for wildlife.

Support for this project comes from the Apis Fund, Binnacle Family Foundation, Charlies E. and Edna T. Brundage Foundation, Jane's Trust Foundation, the Kelsey Trust, Lintilhac Foundation, the Riverledge Foundation, Sarah K. de Coizart Trust, the Vermont Fish & Wildlife Department, and other supporters of the Vermont Center for Ecostudies



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