# Climate, latitude, and land cover predict flying insect biomass in the first year sampling of the German Malaise Trap Program

Ellen A.R. Welti, Petr Zajicek, Manfred Ayasse, Tim Bornholdt, Jörn Buse, Frank Dziock, Rolf A. Engelmann, Jana Englmeier, Martin Fellendorf, Marc I. Förschler, Mark Frenzel, Ute Fricke, Cristina Ganuza, Mathias Hippke, Günter Hoenselaar, Andrea Kaus-Thiel, Klaus Mandery, Andreas Marten, Michael T. Monaghan, Carsten Morkel, Jörg Müller, Stephanie Puffpaff, Sarah Redlich, Ronny Richter, Sandra Rojas Botero, Tobias Scharnweber, Gregor Scheiffarth, Paul Schmidt Yáñez, Rhena Schumann, Sebastian Seibold, Ingolf Steffan-Dewenter, Stefan Stoll, Cynthia Tobisch, Sönke Twietmeyer, Johannes Uhler, Juliane Vogt, Dirk Weis, Wolfgang W. Weisser, Martin Wilmking, Peter Haase

**17 Mar 2021 LTER-D Meeting**

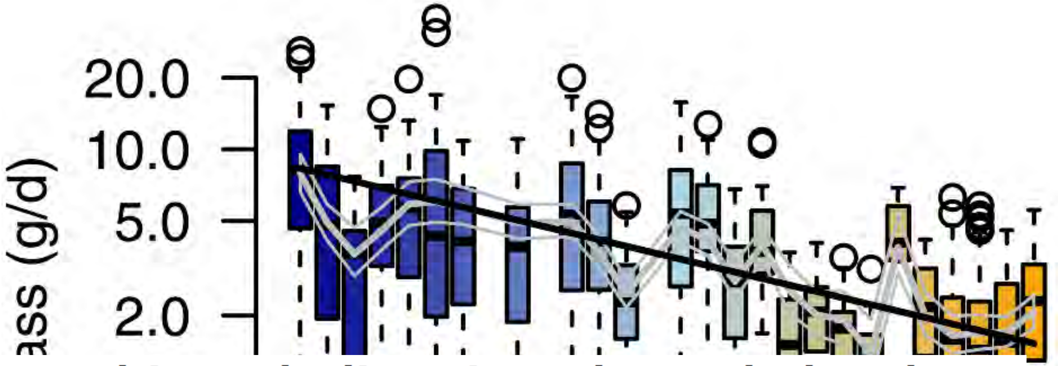
# How are insect populations changing?

2017

PLOS | ONE

## More than 75 percent decline over 27 years in total flying insect biomass in protected areas

Caspar A. Hallmann[1]*, Martin Sorg[2], Eelke Jongejans[1], Henk Siepel[1], Nick Hofland[1], Heinz Schwan[2], Werner Stenmans[2], Andreas Müller[2], Hubert Sumser[2], Thomas Hörren[2], Dave Goulson[3], Hans de Kroon[1]




PNAS

## Climate-driven declines in arthropod abundance restructure a rainforest food web

Bradford C. Lister[a,1] and Andres Garcia[b]

nature

## Arthropod decline in grasslands and forests is associated with landscape-level drivers

Sebastian Seibold, Martin M. Gossner, Nadja K. Simons, Nico Blüthgen, Jörg Müller, Didem Ambarlı, Christian Ammer, Jürgen Bauhus, Markus Fischer, Jan C. Habel, Karl Eduard Linsenmair, Thomas Nauss, Caterina Penone, Daniel Prati, Peter Schall, Ernst-Detlef Schulze, Juliane Vogt, Stephan Wöllauer & Wolfgang W. Weisser

PNAS

## Nutrient dilution and climate cycles underlie declines in a dominant insect herbivore

Ellen A. R. Welti, Karl A. Roeder, Kirsten M. de Beurs, Anthony Joern, and Michael Kaspari

nature ecology & evolution

## Moth biomass increases and decreases over 50 years in Britain

Callum J. Macgregor[1]*, Jonathan H. Williams[1], James R. Bell[2] and Chris D. Thomas[1]*

nature ecology & evolution

## No net insect abundance and diversity declines across US Long Term Ecological Research sites

Michael S. Crossley[1], Amanda R. Meier[1], Emily M. Baldwin[2], Lauren L. Berry[2], Leah C. Crenshaw[2], Glen L. Hartman[3], Doris Lagos-Kutz[3], David H. Nichols[2], Krishna Patel[2], Sofia Varriano[2], William E. Snyder[1] and Matthew D. Moran[2]

Science

## Meta-analysis reveals declines in terrestrial but increases in freshwater insect abundances

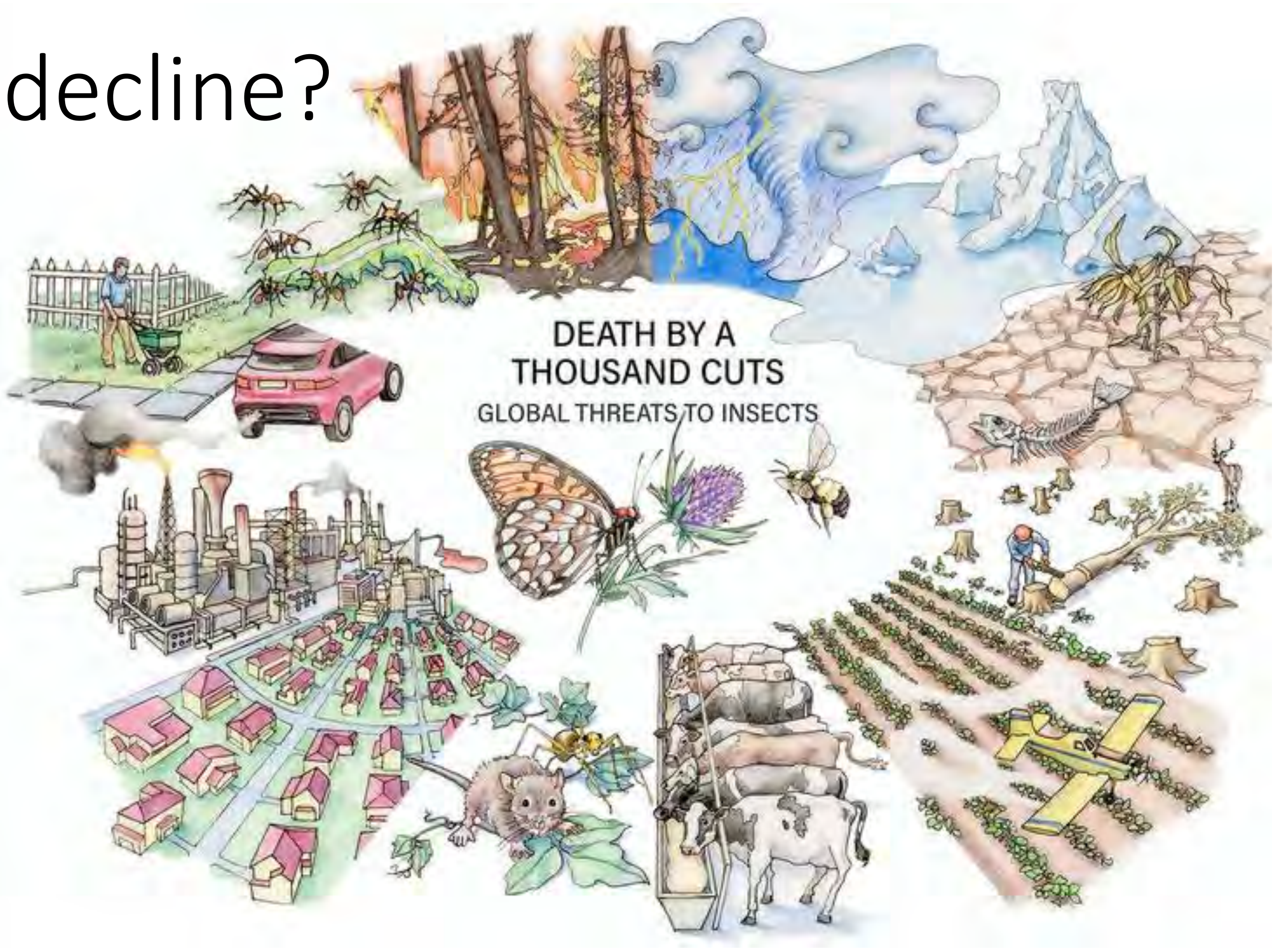
Roel van Klink[1,2,3,*], Diana E. Bowler[1,4,5], Konstantin B. Gongalsky[6,7], Ann B. Swengel[8], Alessandro Gentile[1], Jonathan M. Chase[1,9]

# Why don’t we know more about changing insect populations?

- Few continuous, standardized long-term monitoring efforts
- Few large-scale monitoring efforts
- Insects are extremely diverse

# What causes insect decline?

- Habitat loss/ degradation
- Climate change
- Pesticides/ pollutants




PNAS **Insect decline in the Anthropocene: Death by a thousand cuts**

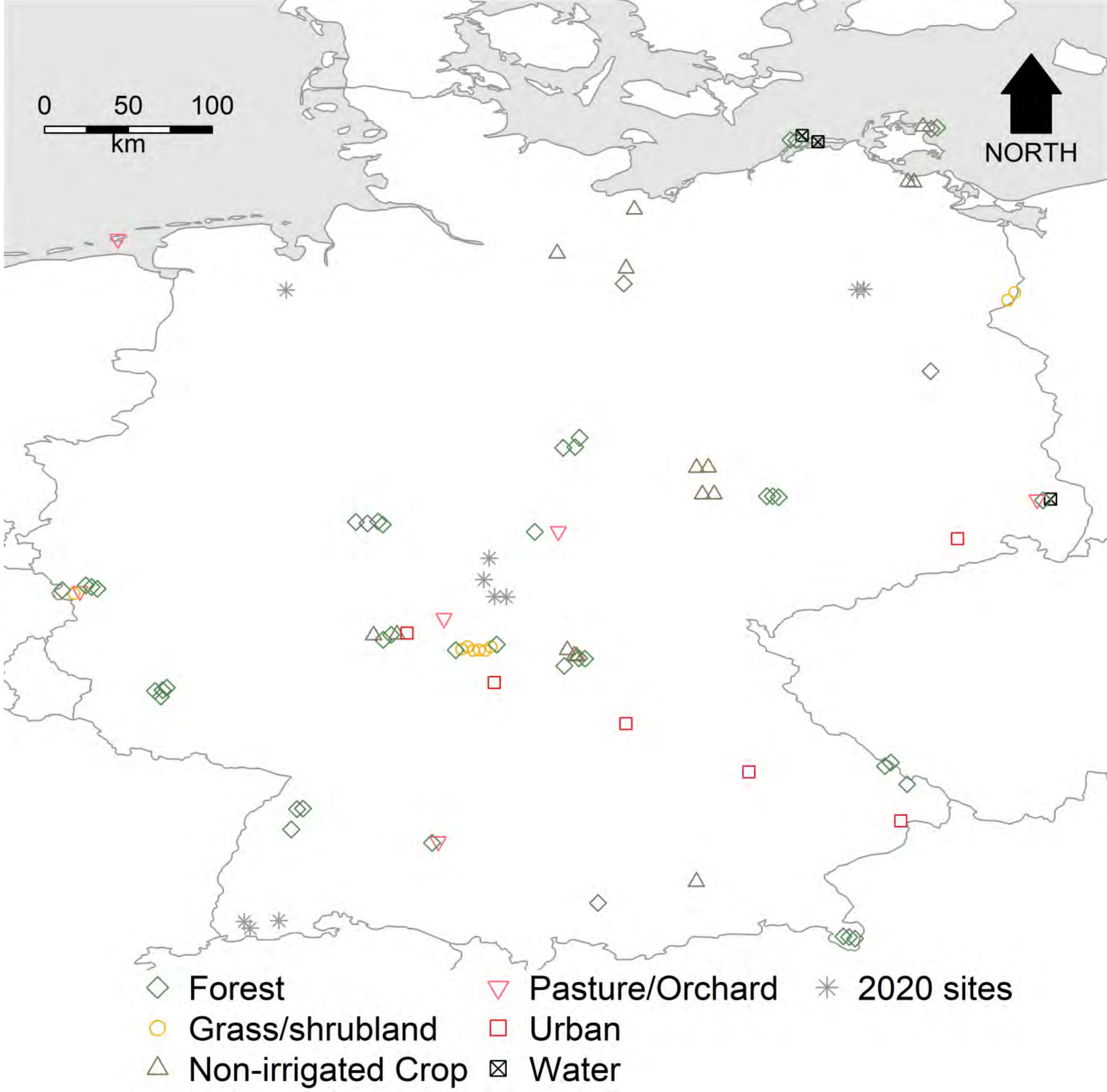
David L. Wagner, Eliza M. Grames, Matthew L. Forister, May R. Berenbaum, and David Stopak

# German Malaise Trap Program

- Since 2019
- Flying insect monitoring across Germany which is:
- Standardized
- Large scale
- Full growing season
- Multi-year continuous

# German Malaise Trap Program

- 31 LTER-D sites in biosphere reserves and national parks (25 running in 2019)
- 8 additional sites in Bavaria
- 84 trap locations

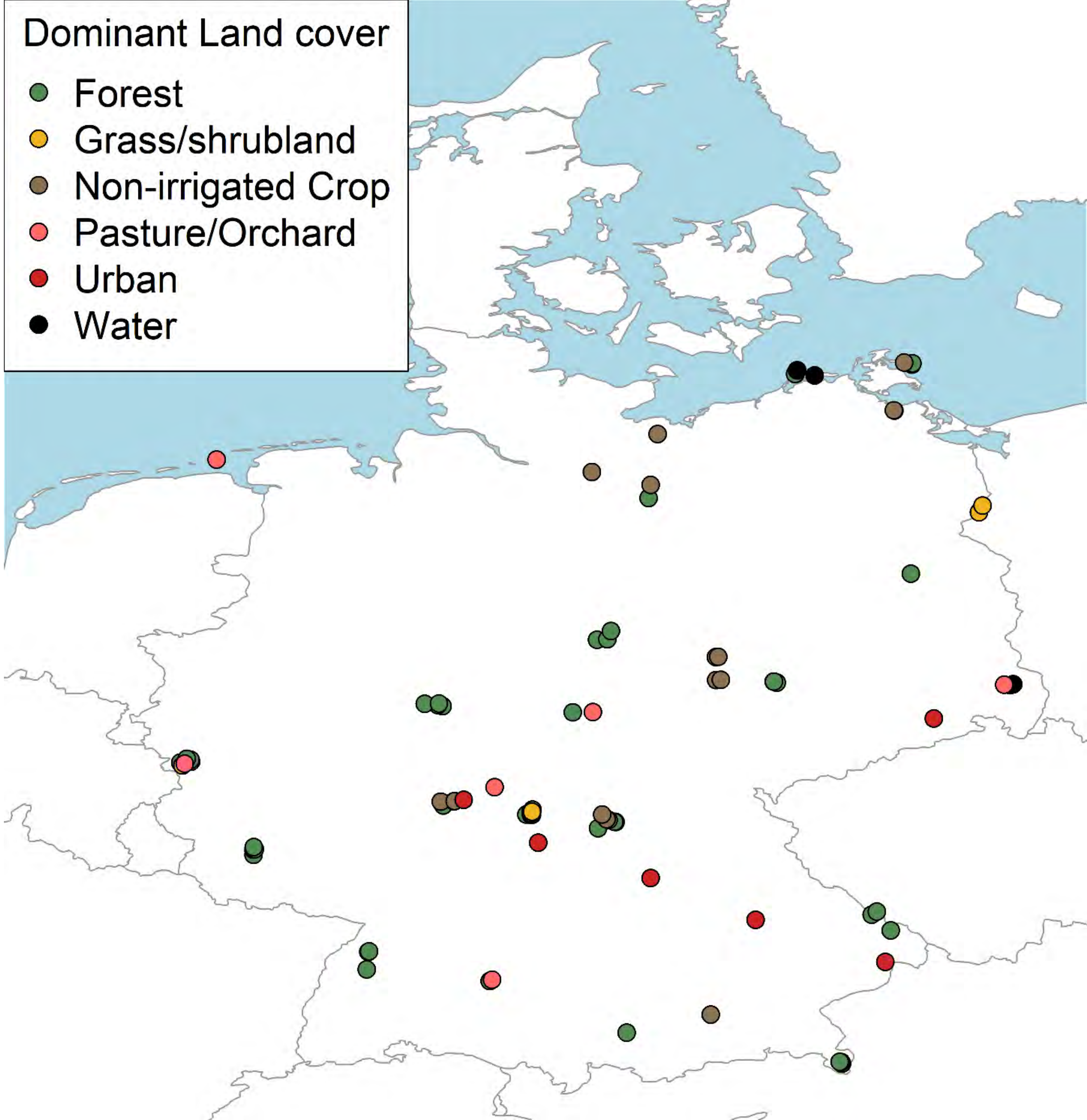


# Biomass

- Represents whole flying insect communities
  “One number to rule them all”
- An estimate of energy availability
- A measure of ecosystem function
- Future work using DNA barcoding

# What drives variation in flying insect biomass across Germany?

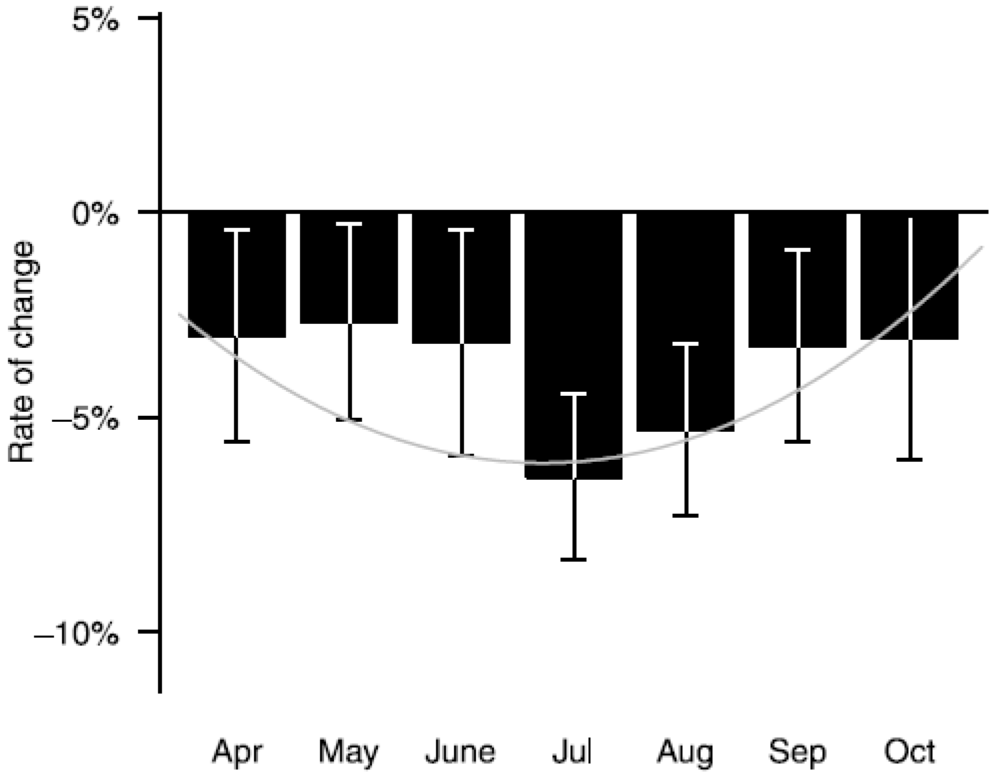
- Temperature
- Precipitation
- Surrounding land cover (e.g. % urban, forest, grassland, cropland)



# More than 75 percent decline over 27 years in total flying insect biomass in protected areas

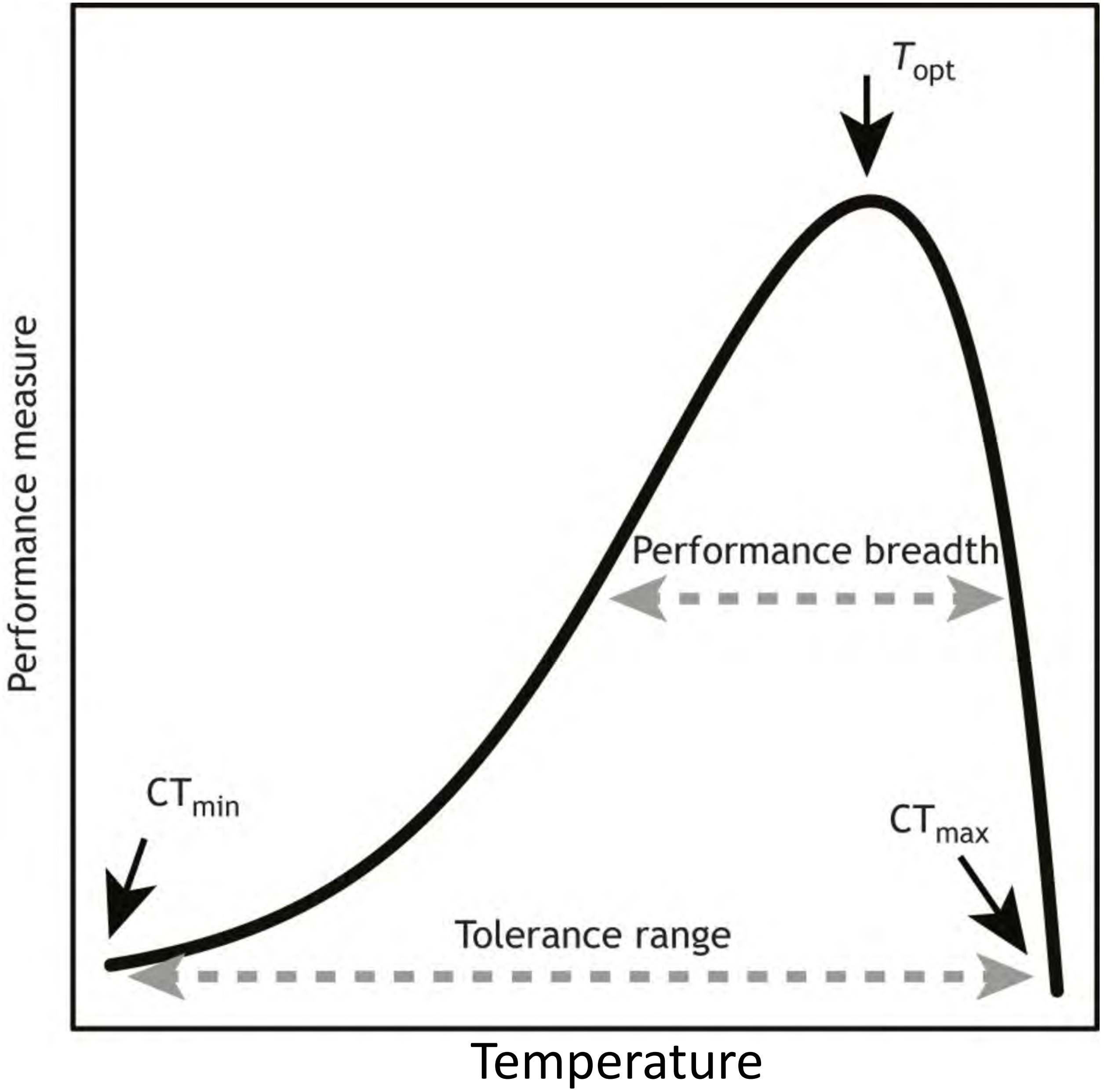
Caspar A. Hallmann[1]*, Martin Sorg[2], Eelke Jongejans[1], Henk Siepel[1], Nick Hofland[1], Heinz Schwan[2], Werner Stenmans[2], Andreas Müller[2], Hubert Sumser[2], Thomas Hörren[2], Dave Goulson[3], Hans de Kroon[1]

- Temperature (+ over years but – over season)
- Precipitation (-)
- Surrounding land cover (none)
- Maximum 23 sites sampled within one year



# Hypotheses

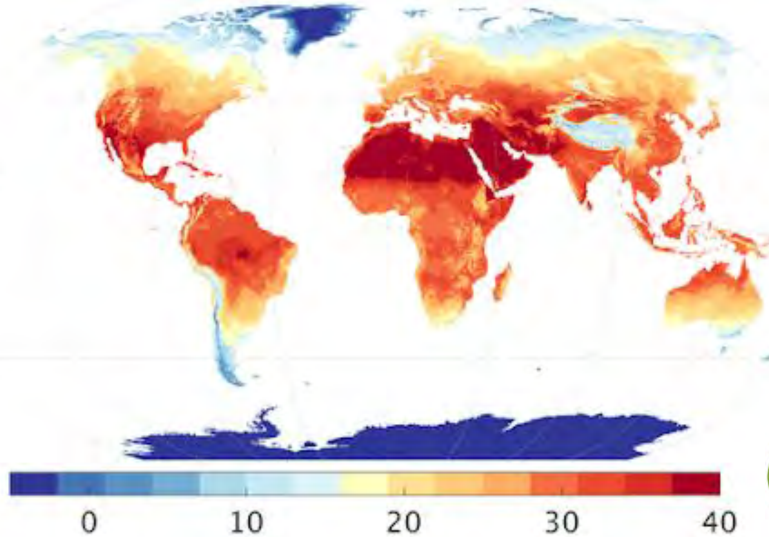
- Insect biomass will be lower in human impacted land cover types
- Insect biomass will decrease with high precipitation
- Insect biomass will have a "hump-shaped" relationship with temperature, consistent with Thermal Performance Theory




Levesque & Marshall 2021

# Methods

- Samples collected every ~2 weeks
- Sieved and weighed
- Climate data extracted from TerraClimate and WorldClim (tmax, tmin, precipitation)
- Land use data extracted from CORINE (2018) in 1km buffer

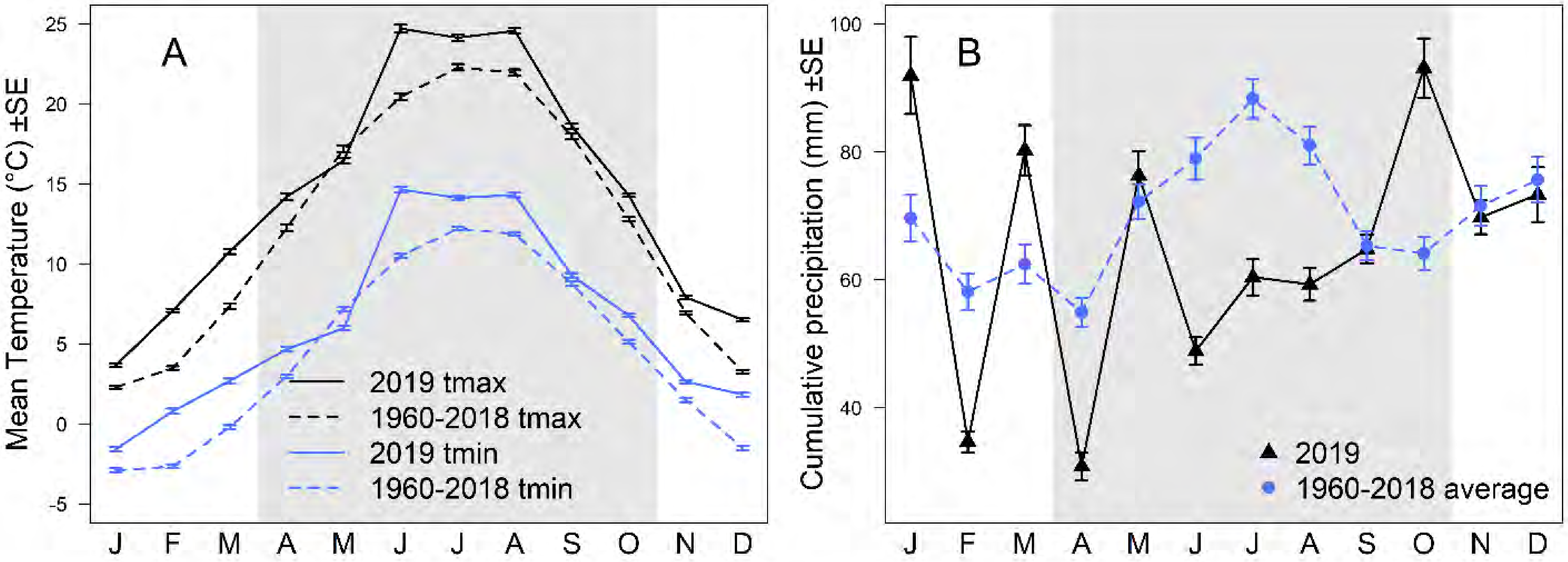



QGIS

# Methods

- Mixed models
- Fixed effects: temperature, 2nd degree polynomial of temperature, Δ temperature, precipitation, % surrounding area of dominant land cover types, latitude, elevation, sampling period
- Random effect: location
- AICc model selection

# 2019 was a hot year (with a dry summer)



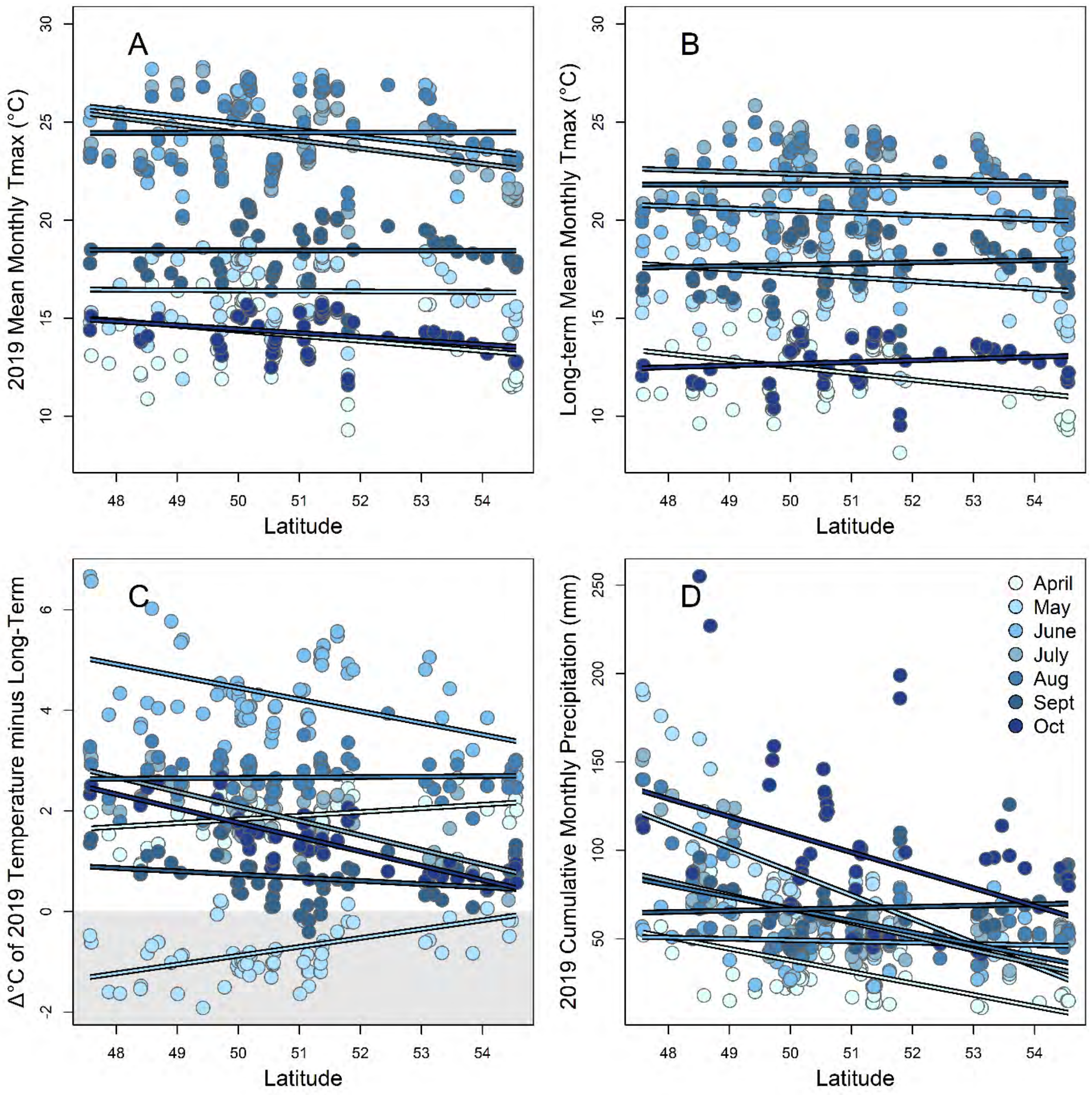
# Germany experienced a greater temperature gradient in 2019: warmer South

(A) 2019 Temperature: $P = 0.06$ (-)

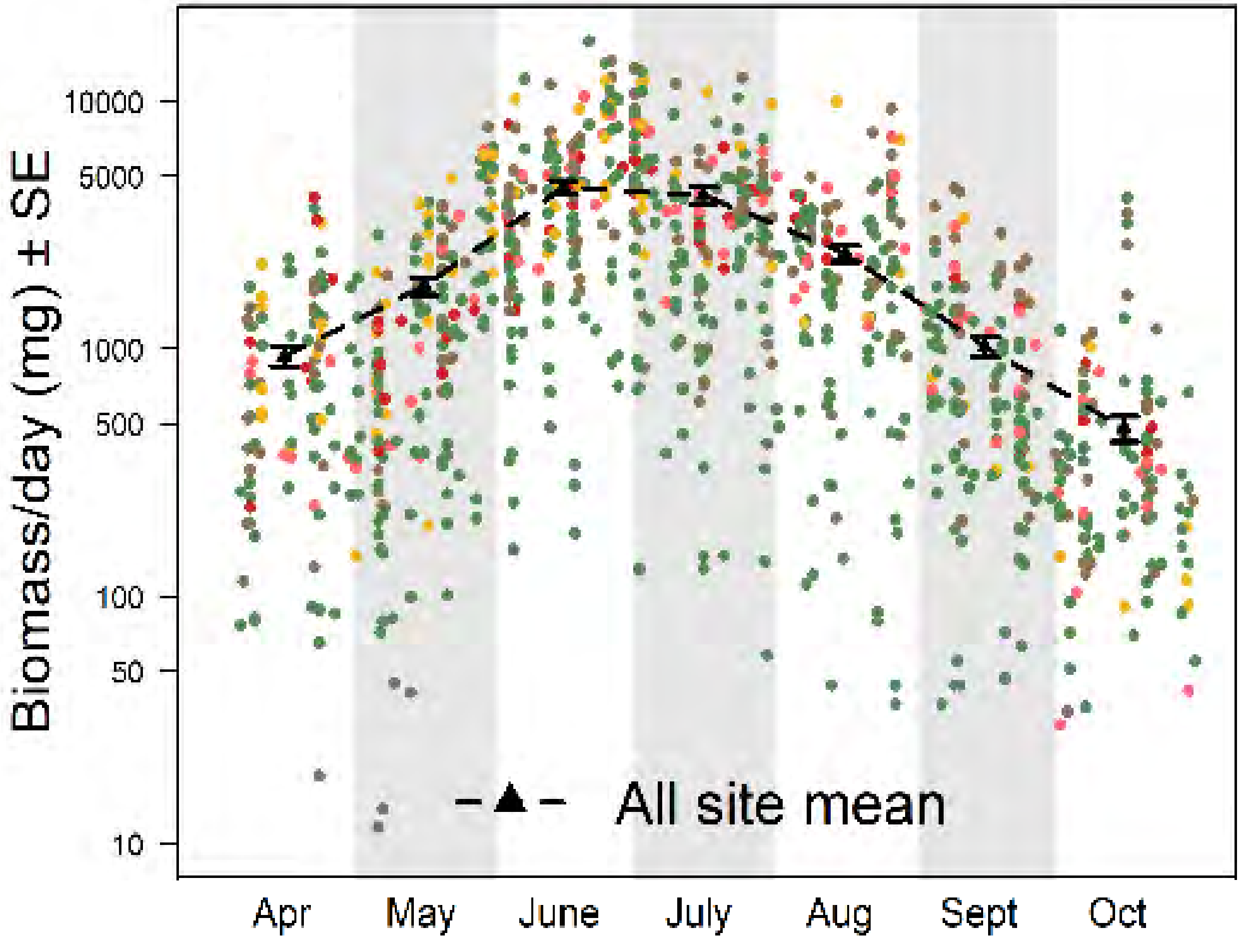
(B) Long-Term Temperature: $P = 0.21$

(C) Δ Temperature: $P = 0.01$ (-)

(D) 2019 Precipitation: $P < 0.001$ (-)

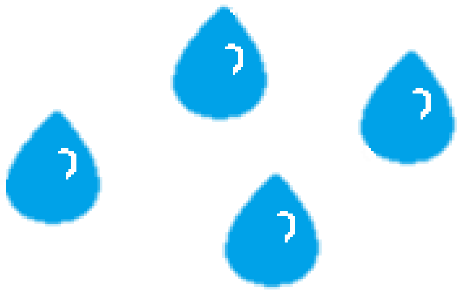


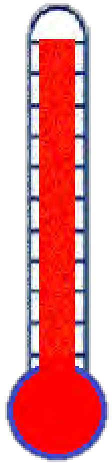
# Biomass across the growing season

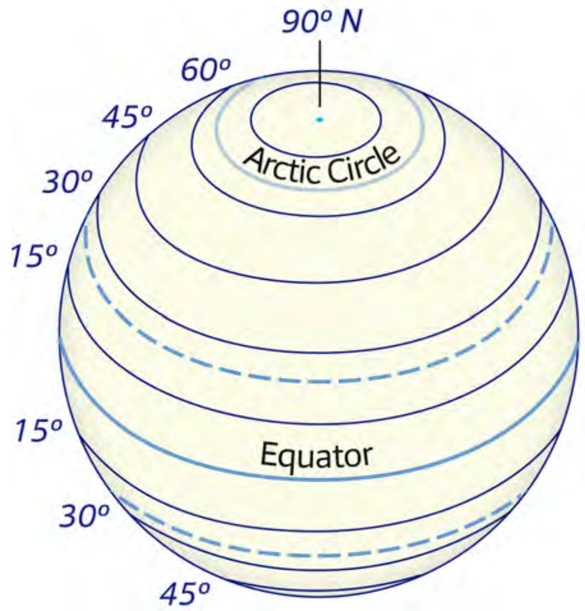



- Mean: 2,329 ± 79 SE mg/day
- peak: late June: 5,356 ± 401 SE mg/day
- Hallmann et al. (2017): May-Sept 1989: 9,192 mg/day May-Sept 2016: 2,531 mg/day
- This study May-Sept: 2,404 mg/day
- Hallmann et al. traps ~50% larger opening

# Flying Insect Biomass driven by:



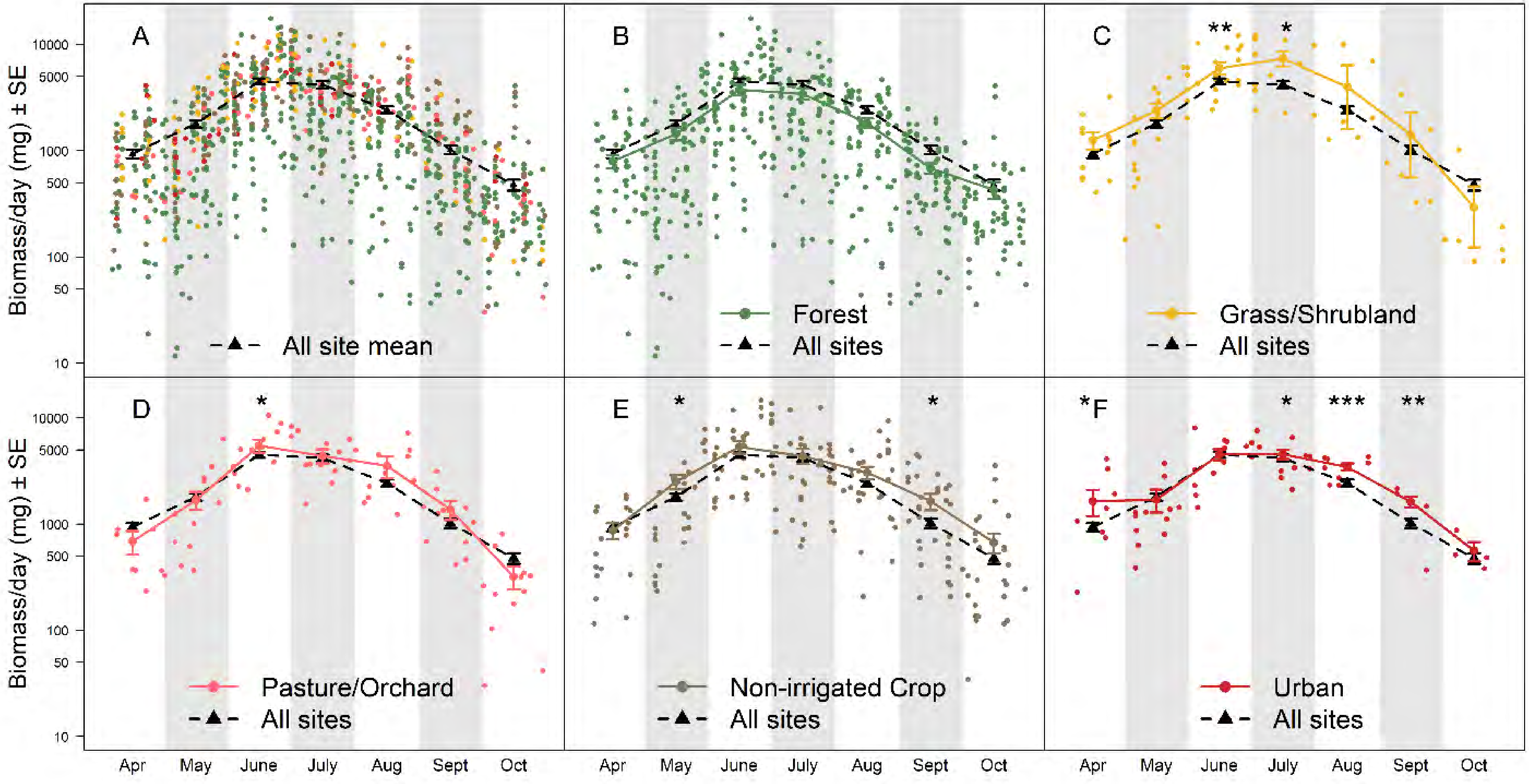





- Sampling period
- Temperature (+)
- Δ Temperature over long-term (-)
- Precipitation (-)
- Latitude (-)
- % Forest (-)

Marginal $R^2 = 0.51$
Conditional $R^2 = 0.74$

# Land Cover



A
B
C
D
E
F
Biomass/day (mg) ± SE
10000
5000
1000
500
100
50
10
All site mean
Forest
All sites
Grass/Shrubland
All sites
Pasture/Orchard
All sites
Non-irrigated Crop
All sites
Urban
All sites
**
*
*
*
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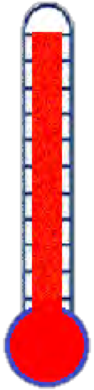
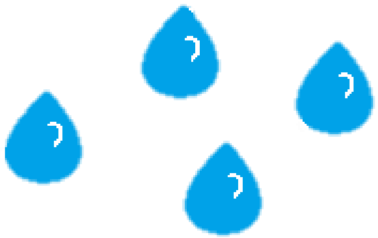
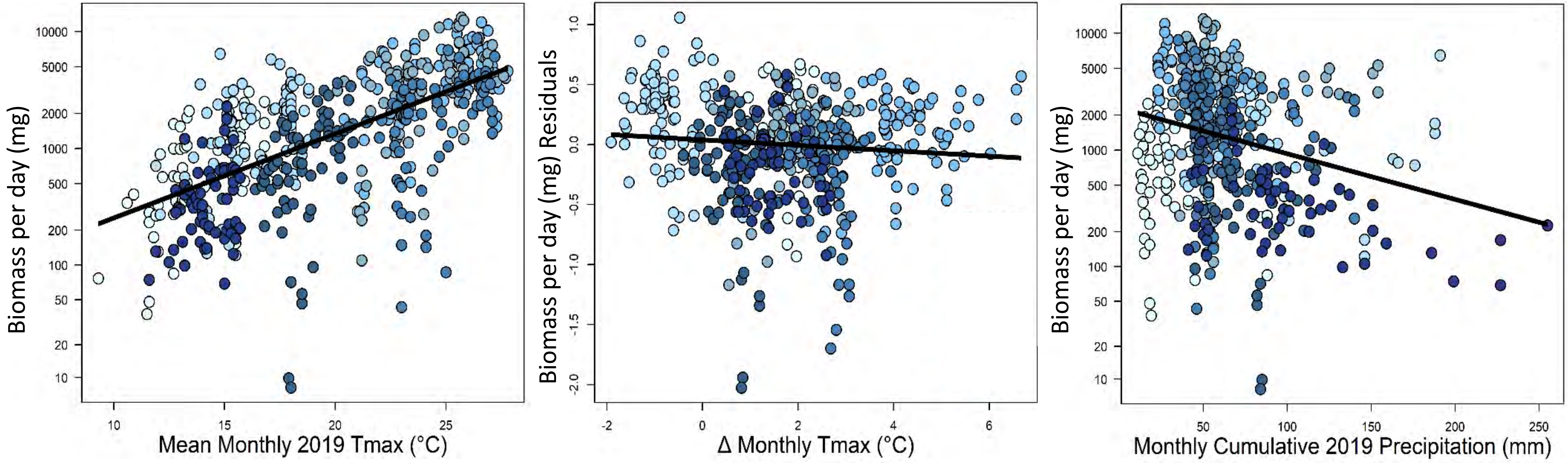
**
Apr
May
June
July
Aug
Sept
Oct

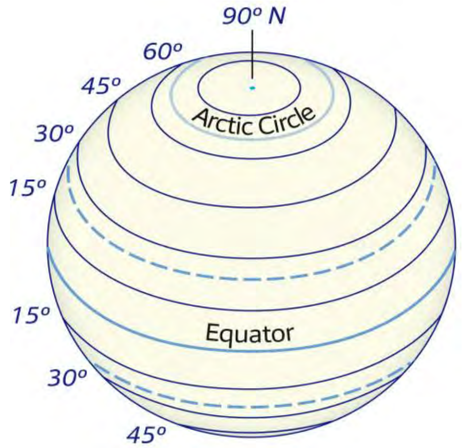
# Strong effects of local climate on insect biomass

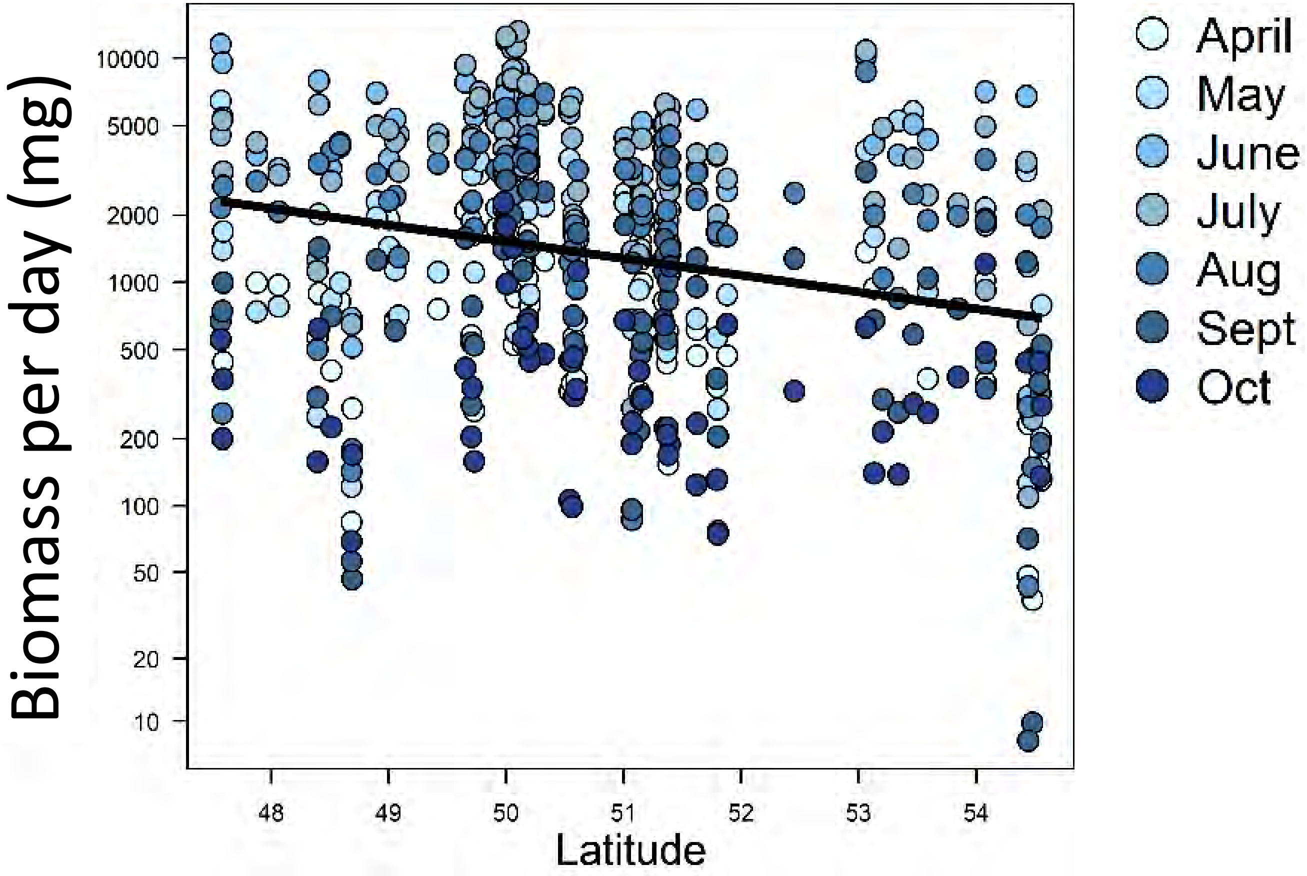




# Flying insect biomass declined with latitude




# How does the effect of temperature on insect flying biomass vary with latitude?

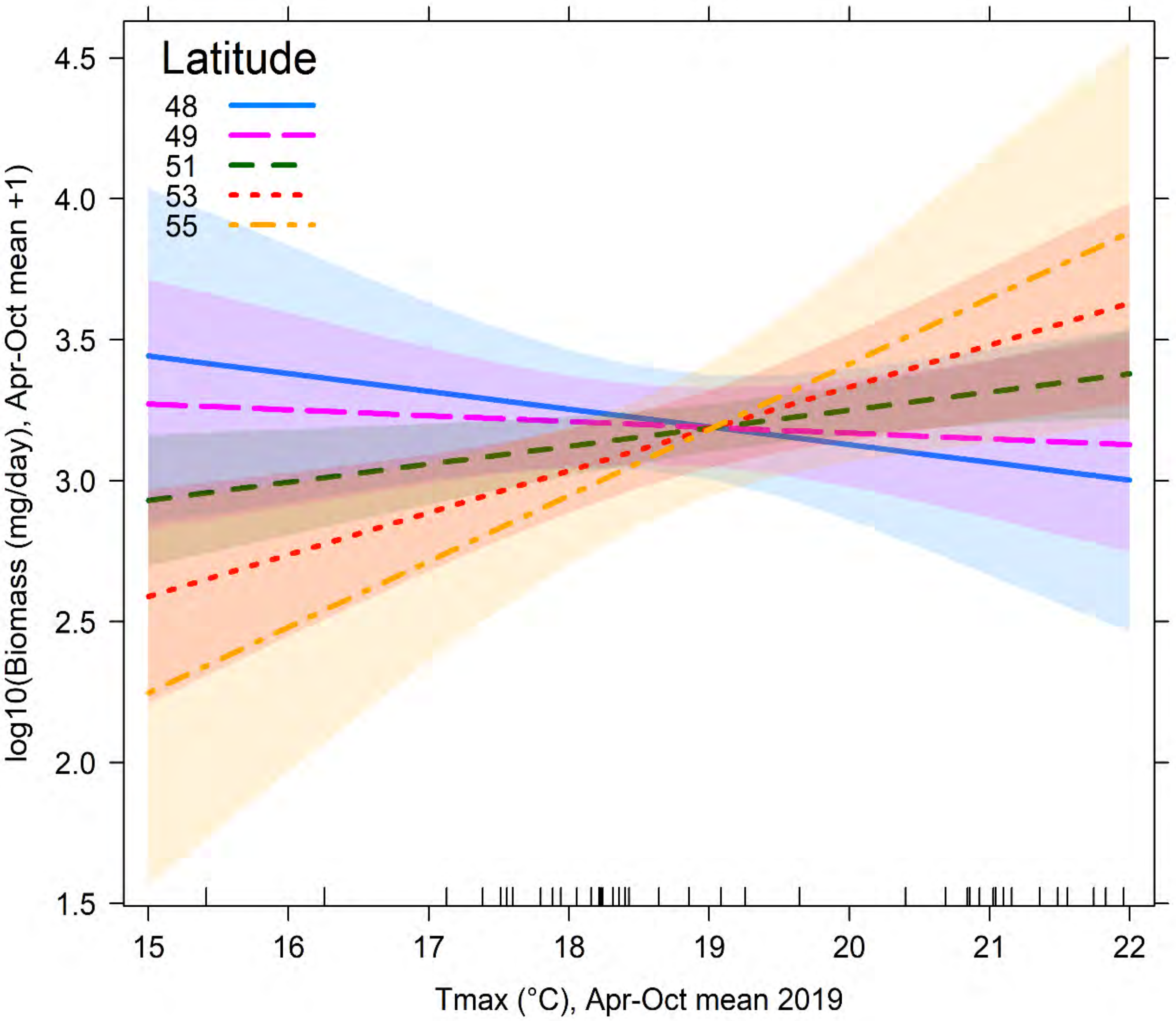
- No temperature X latitude interaction in full model due to variance inflation
- **Hypothesis:**

Stronger positive effects of temperature in colder sites

- Interaction model at site level, using only sites with complete sampling (n = 48)

# Temperature X Latitude Interaction

The effect of 2019 temperature varies from negative to positive with increasing latitude ($F_{3,44}$ = 4.3, $R^2$ = 0.23, *P* = 0.01)



# Conclusions

- Hypothesis: Insect biomass will be lower in human impacted land cover types

- Results: Less flying insect biomass in forests
- Malaise traps not as effective in forests
- Less floral resources



# Conclusions

- Hypothesis: Insect biomass will decrease with high precipitation

- Result: Negative effect of precipitation
- Reduced times when insects are flying
- Negative effects of precipitation on insect mortality, plants/flowers



# Conclusions

- Hypothesis: Insect biomass will have a “hump-shaped” relationship with temperature, consistent with Thermal Performance Theory
- Results:
- Positive overall effect of temperature on flying insect biomass
- BUT negative effect of Δ Temperature (2019 minus Long-term mean)
- Negative effects of rapid temperature rise, even in colder climates
- Temperature X latitude interaction

# Acknowledgements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Bavarian State Ministry of Science and the Arts

eLTER

DFG Deutsche Forschungsgemeinschaft

SENCKENBERG world of biodiversity

Nationale Naturlandschaften