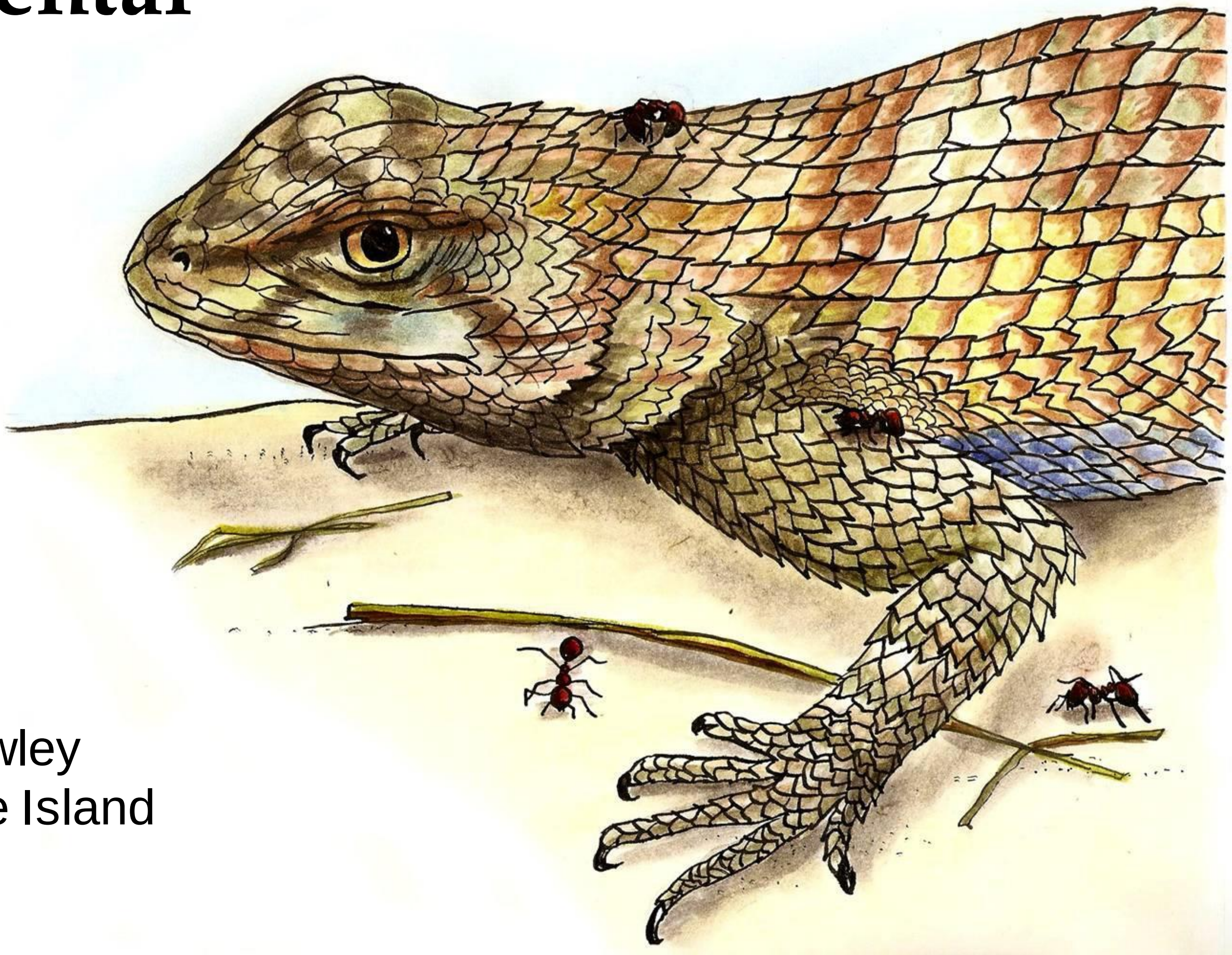
Data Analysis in the Anthropocene: How Do Lizards Respond to Environmental Change?



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Environmental Uncertainty

- Increasing
  - Climatic variability
  - Invasive species
  - Habitat alteration
- Diverse impacts
- Novel evolutionary pressures
- Opportunity to study adaptation in action

What new challenges do organisms face?
Can they adapt quickly enough to persist?
What mechanisms allow for adaptive changes?


Insight into foundational processes
Predicting future changes and their impacts
Making effective conservation decisions

Red Imported Fire Ant Invasion

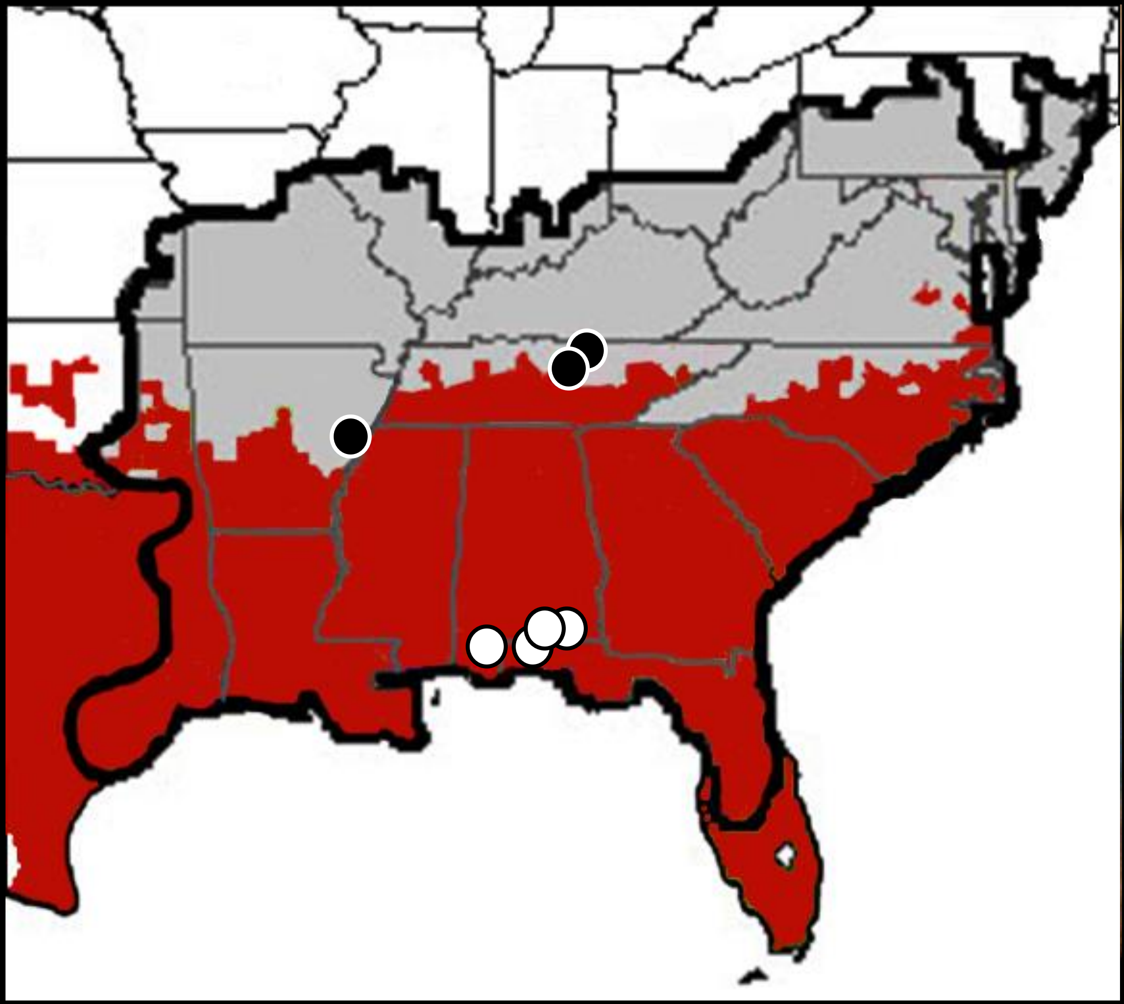
- Predicted to occupy >50% of Earth's surface
- Major human and agricultural pest
- Introduced in Mobile, AL in 1930s
- Significant threat to native species

A. Wild

Fence Lizard/Fire Ant System

Red Imported Fire Ants

- Predator/toxic prey
- Fewer than 12 ants can kill adult lizards
- Overlap with range of Eastern Fence Lizard
- Can study lizards from Invaded/ Uninvaded sites



Natural Fence Lizard Behavior

- Natural reaction to predator presence is to freeze
  - Birds of Prey
  - Snakes
- Crypsis effective vs. visual predators but not Fire Ants

G. Rasberry

W. Majoros

Fence Lizards Adapt Behaviorally

At Fire Ant Invaded sites:

- Increase in twitch and flee behaviors
  - Removes ants
- Longer hind limbs
  - Supports flight and twitching
- Higher stress responsiveness
  - Supports fleeing

Langkilde, 2009, *Ecology*

Research Questions

How do Fire Ants exert pressure on fence lizard populations?

Do effects vary by life stage?

Do adaptive changes vary by life stage?

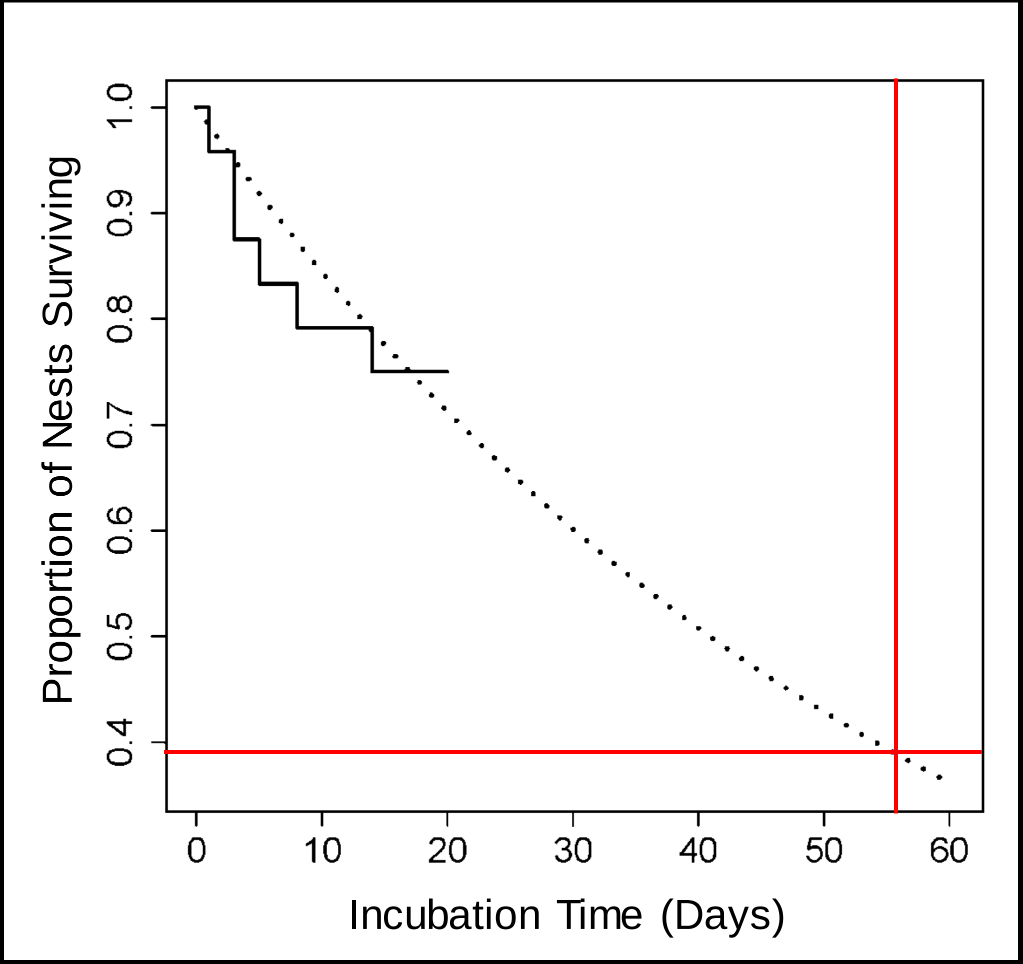
Fence Lizard Eggs

- Habitat overlap with fire ant mounds
- Fire Ants can penetrate fence lizard eggs
  - Newman *et al*. 2014. Herpetology Notes.
- Potential for nest site selection?

Cannot twitch or flee to avoid attacking Fire Ants

Fire Ants Prey On Fence Lizard Nests

- Six of 25 nests preyed on by Fire Ants
- Up to 61% of nests at risk during incubation
- No effect of
  - Distance to nearest Fire Ant mound (β=-0.076, df=1, *p*=0.32)
  - Canopy cover (β=-0.022, df=1, *p*=0.57)



Thawley and Langkilde. 2016. J Herpetology.

Conclusions

- Difficult to avoid predation via nest site selection
- No evidence of eggshell thickening (Goldy-Brown, unpubl. data)

Fire Ants likely have strong impacts on fence lizard hatching success and survival

Fence Lizard Ontogeny

- Adults:
  - Behavioral adaptation
- Juveniles:
  - Smaller
  - More vulnerable to venom
  - Eat lots of ants

Aims:

- Lethal Effects:
  - Mortality
- Sublethal Effects:
  - Growth
  - Body Condition

Difficult to assign causality in free-living lizards…

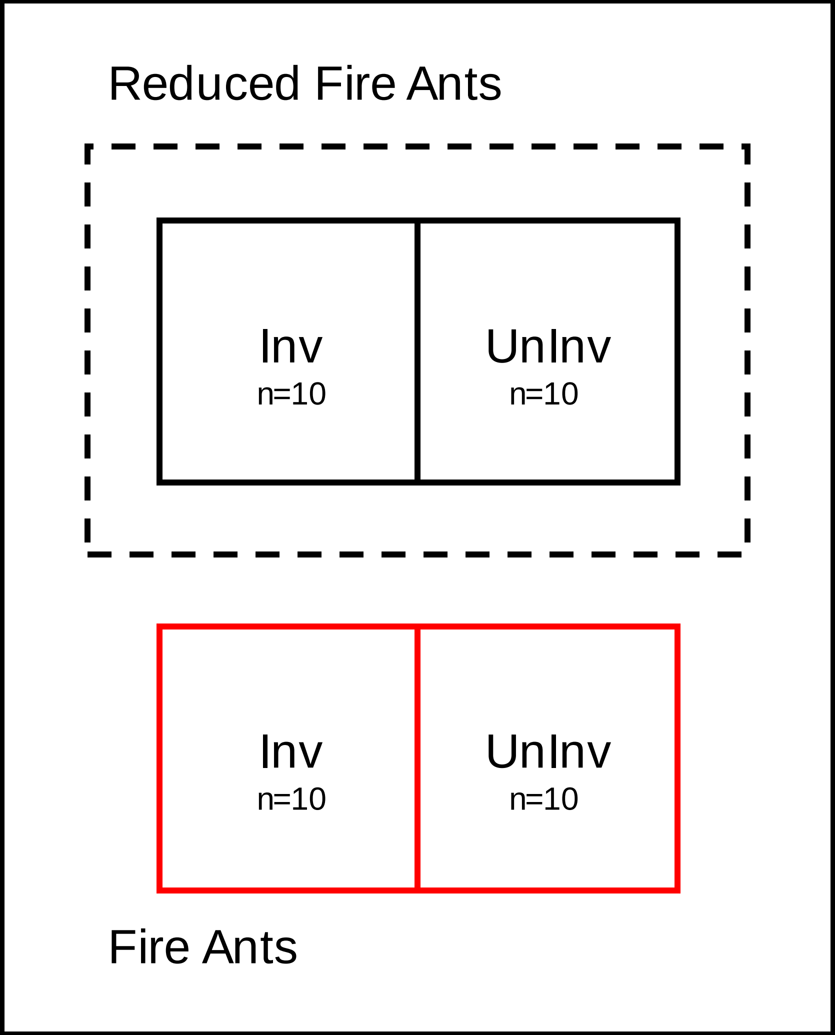
Enclosures

Experimental Setup

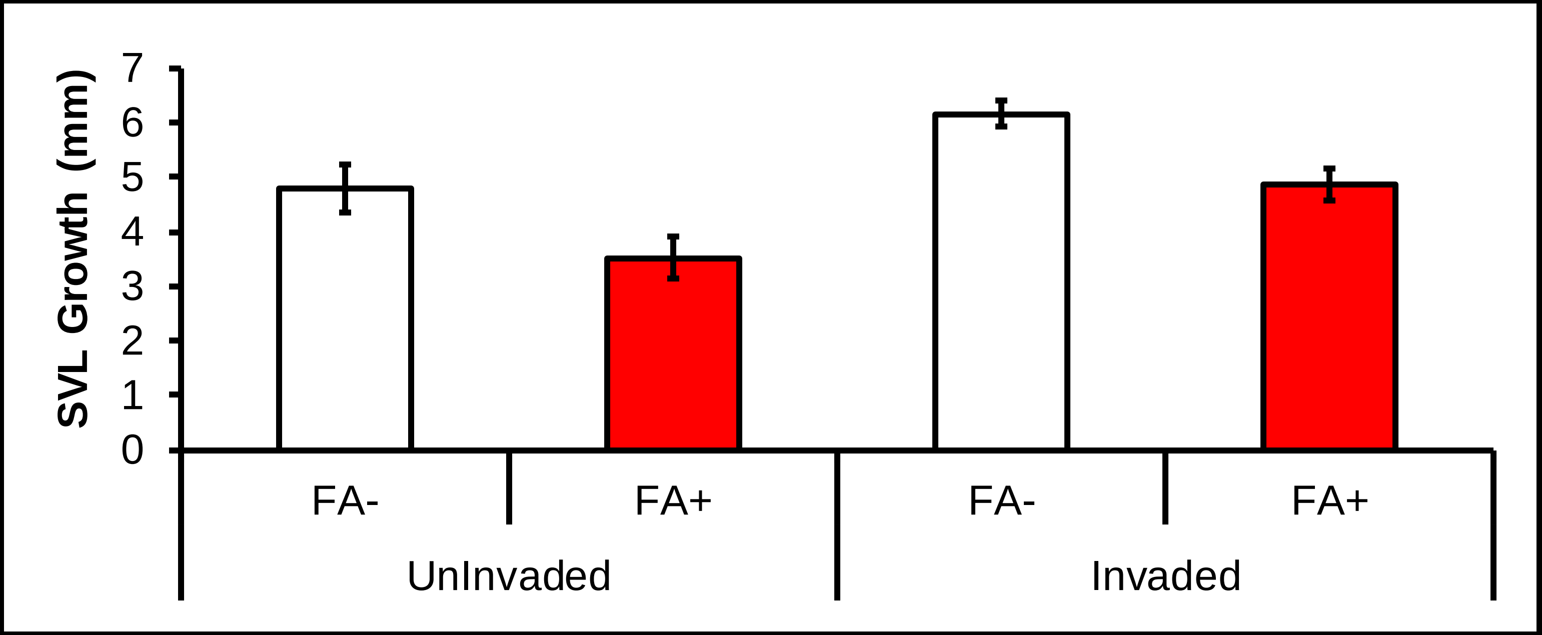
- Reduced Fire Ants in two enclosures

Experimental Setup

- Reduced Fire Ants in two enclosures
- Two week trials in paired enclosures

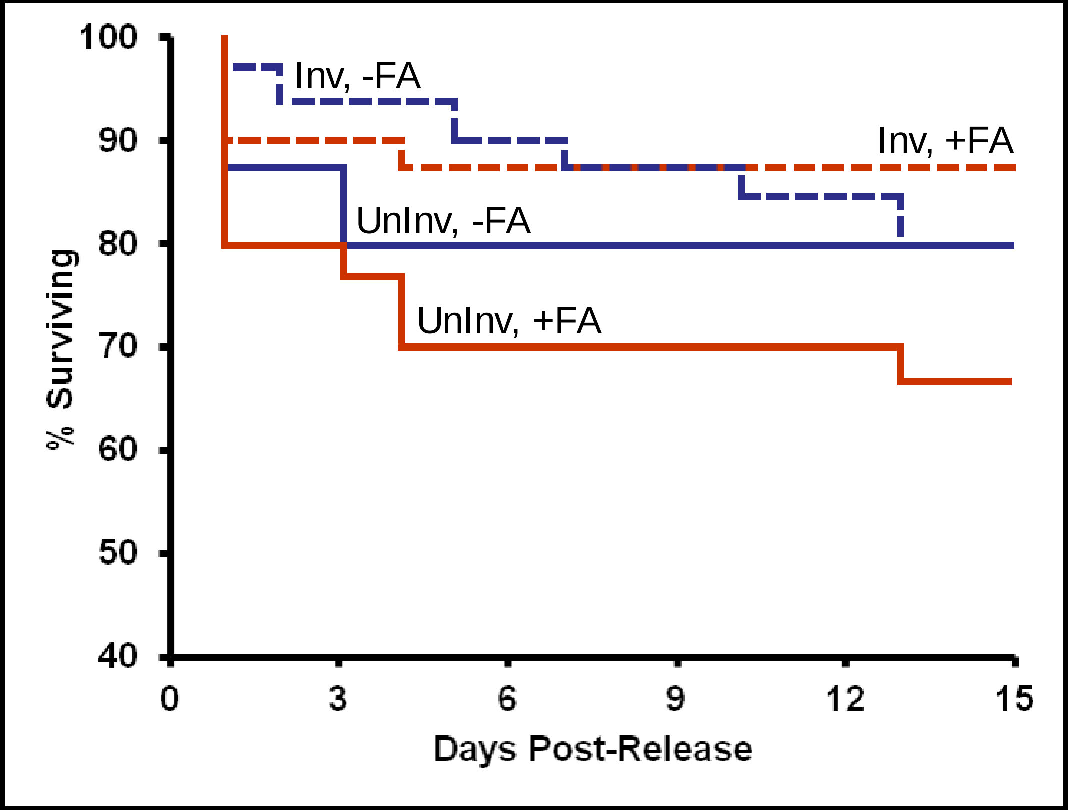


Fire Ants Reduce Juvenile Growth



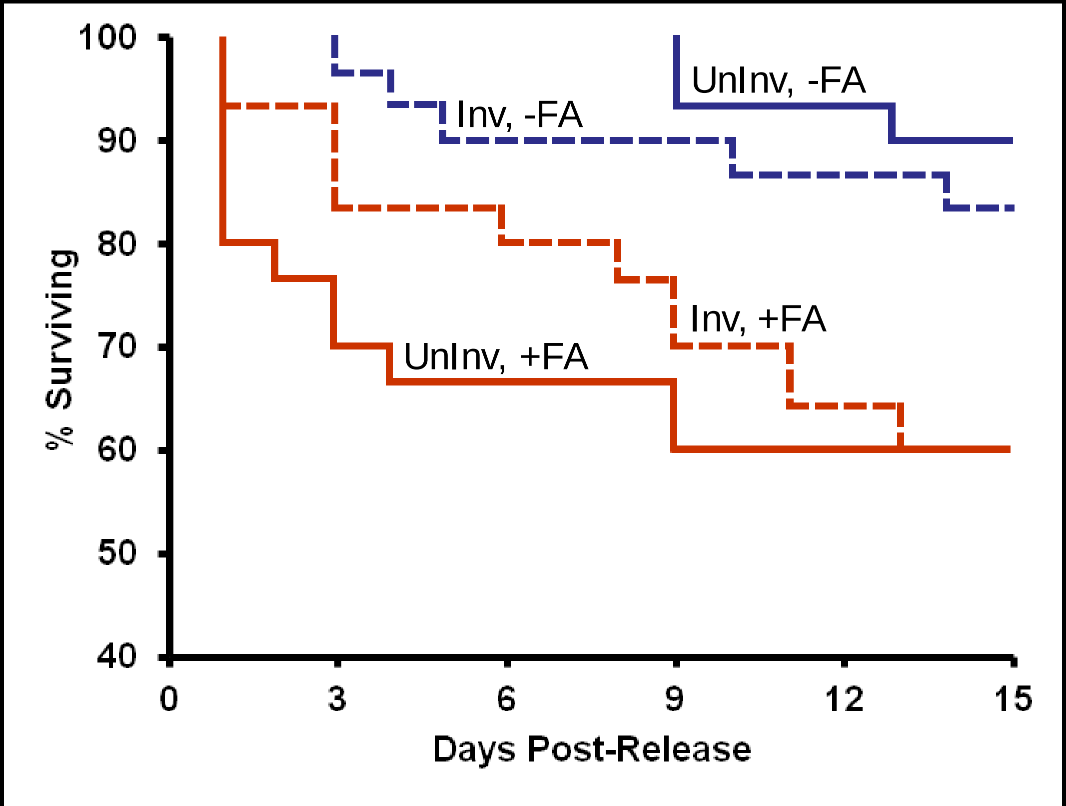
- High Fire Ant density reduces growth
  (β=-1.283, $F_{1,85}$=20.130, p<0.001)
- No difference in adult growth

Juvenile Survival



- No effect of Fire Ant density on survival

Adult Survival



- High Fire Ant density reduced survival
  (β=0.109; 95% CI:(0.021, 0.196))
- No significant effect of invasion status

Effects of Fire Ants Vary Across Ontogeny

	Eggs	Juveniles	Adults
Behavior	—	—	↑
Growth		↓	—
Survival	↓	—	*↓?

Does Previous Exposure to Fire Ants Affect Adult Lizard Survival?

Does Exposure to Fire Ants Affect Lizard Survival?

W. Majoros

Expected:

- With high Fire Ant density, lizards from Invaded sites had higher survival

Unexpected:

- With low Fire Ant density, lizards from Invaded sites had lower survival

Could anti-Fire Ant behavioral adaptations be maladaptive in the absence of Fire Ants?

Does Exposure to Fire Ants Affect Lizard Survival?

Aims:

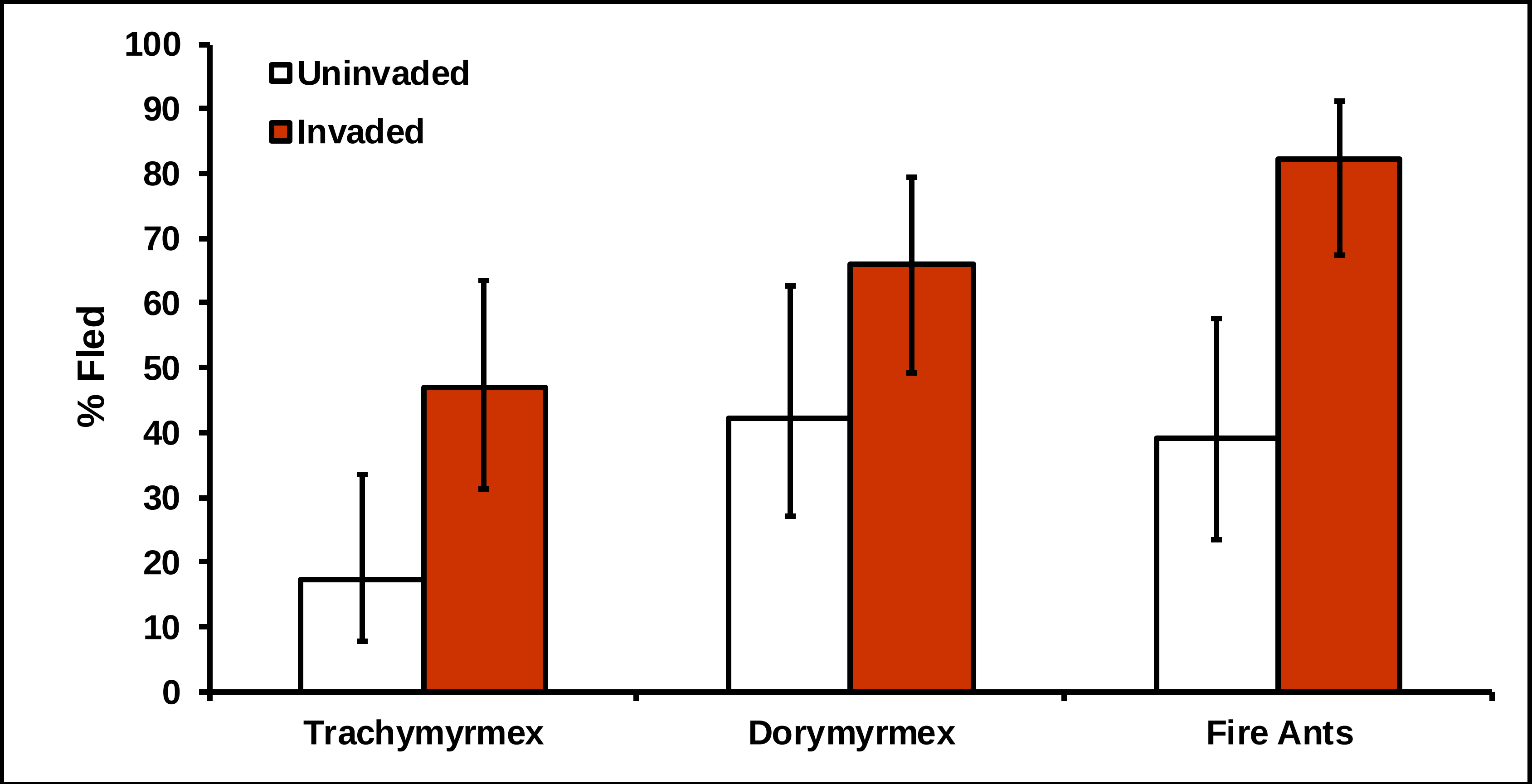
1. How generalized is this anti-Fire Ant response?
   - Test reactions to 2 types of native ants
     - *Dorymyrmex sp.*
     - *Trachymyrmex sp.*

A. Wild

2. Do lizards at Fire Ant Invaded sites experience higher injury rates from predators?

Thawley and Langkilde. 2017. Animal Behavior.

Invaded Lizards Flee More From All Ants

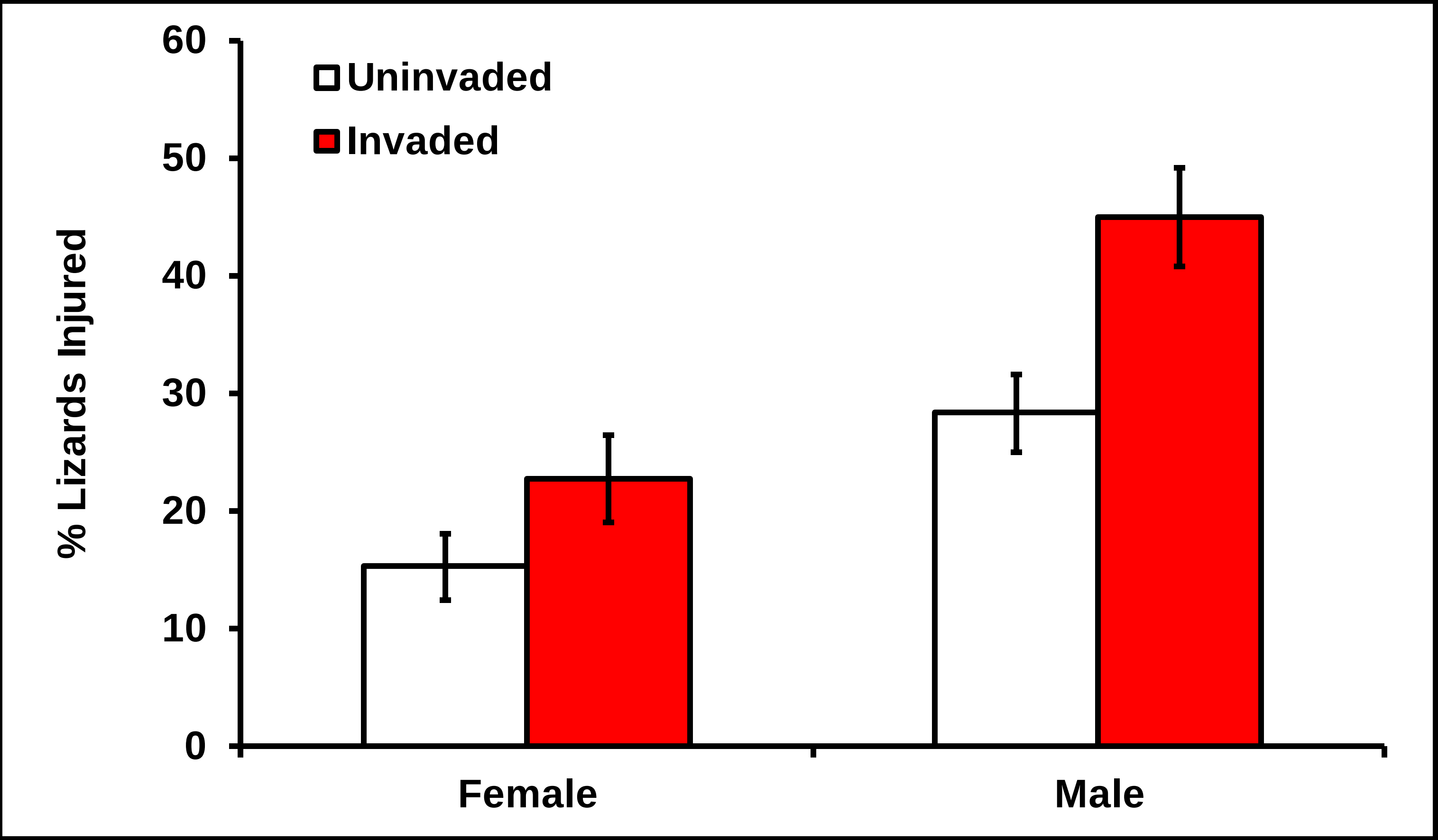


Inv: $F_{1,285}=14.88$, $p<0.001$
Trt: $F_{1,285}=8.82$, $p<0.001$
Sex: $F_{1,285}=6.25$, $p<0.013$

Field Injury Rates

- Examined lizards from Invaded and Uninvaded sites for signs of attempted predation
  - Scars
  - Broken tails
  - Stumps


Higher Injury Rates at Invaded Sites



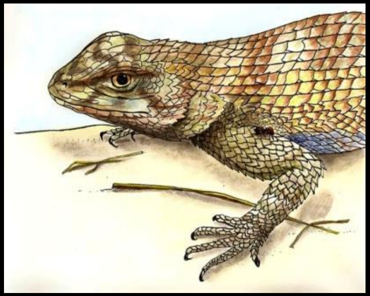
Inv: $F_{1,334}$=6.01, p<0.015
Sex: $F_{1,334}$=20.99, p<0.001

The Horns of a Furious Dilemma

Lizards are faced with a predation trade-off

- Fire Ants are an immediate threat, but…
- Anti-Fire Ant behavior may draw attention of native predators
  - Reacting unnecessarily to native ants may increase threat of predation

Kevin Cole



M. Quinn

Fitness Consequences

Adults:

- Avoiding Fire Ants may increase susceptibility to native predators

Juveniles:

- Avoiding Fire Ants may lower growth
  - Reduced lifetime reproduction

Conclusions

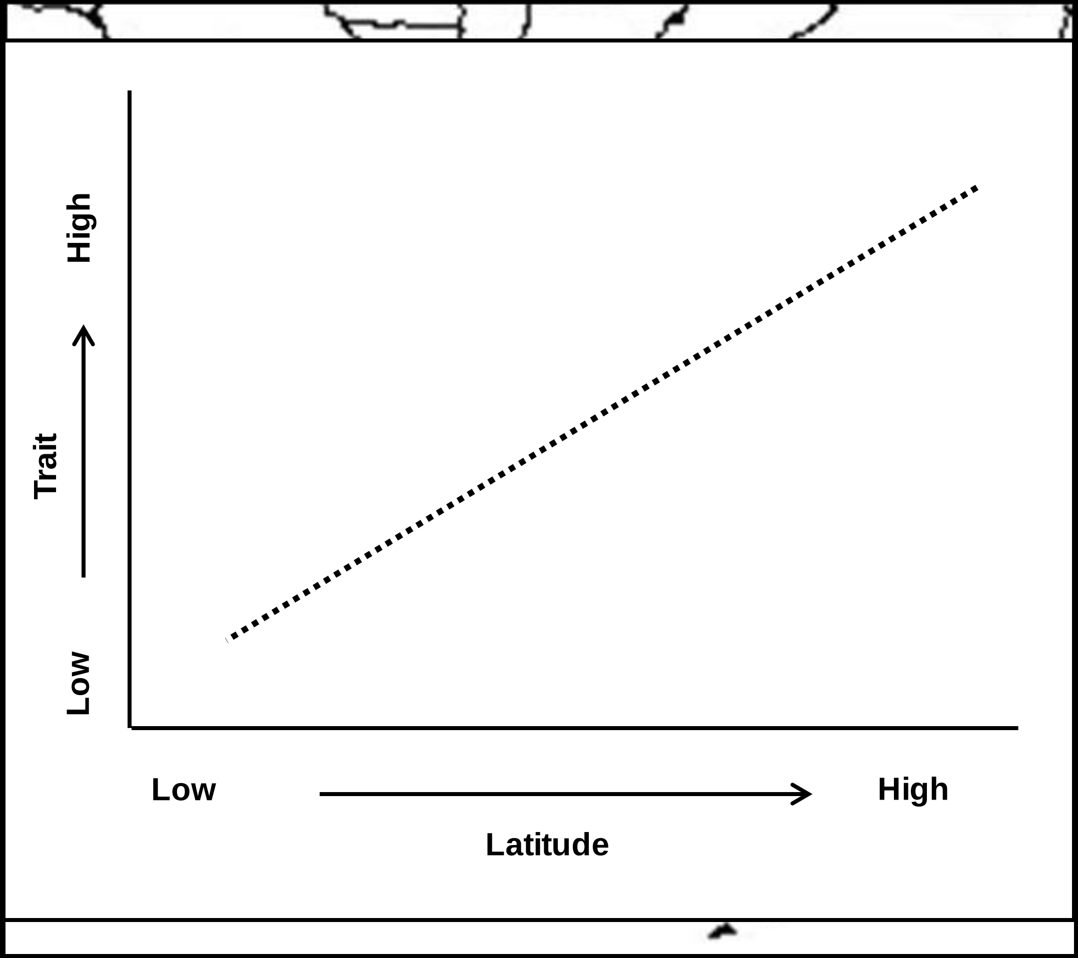
- Rapid adaptation may ameliorate novel pressures but expose organisms to other impacts
- Impacts of invasive species are diverse and may vary strongly with life stage

Are these impacts and adaptations to them replicated over large spatial scales?

Do fire ants alter preexisting spatial patterns in fence lizard traits?

Problem:

- No time machine

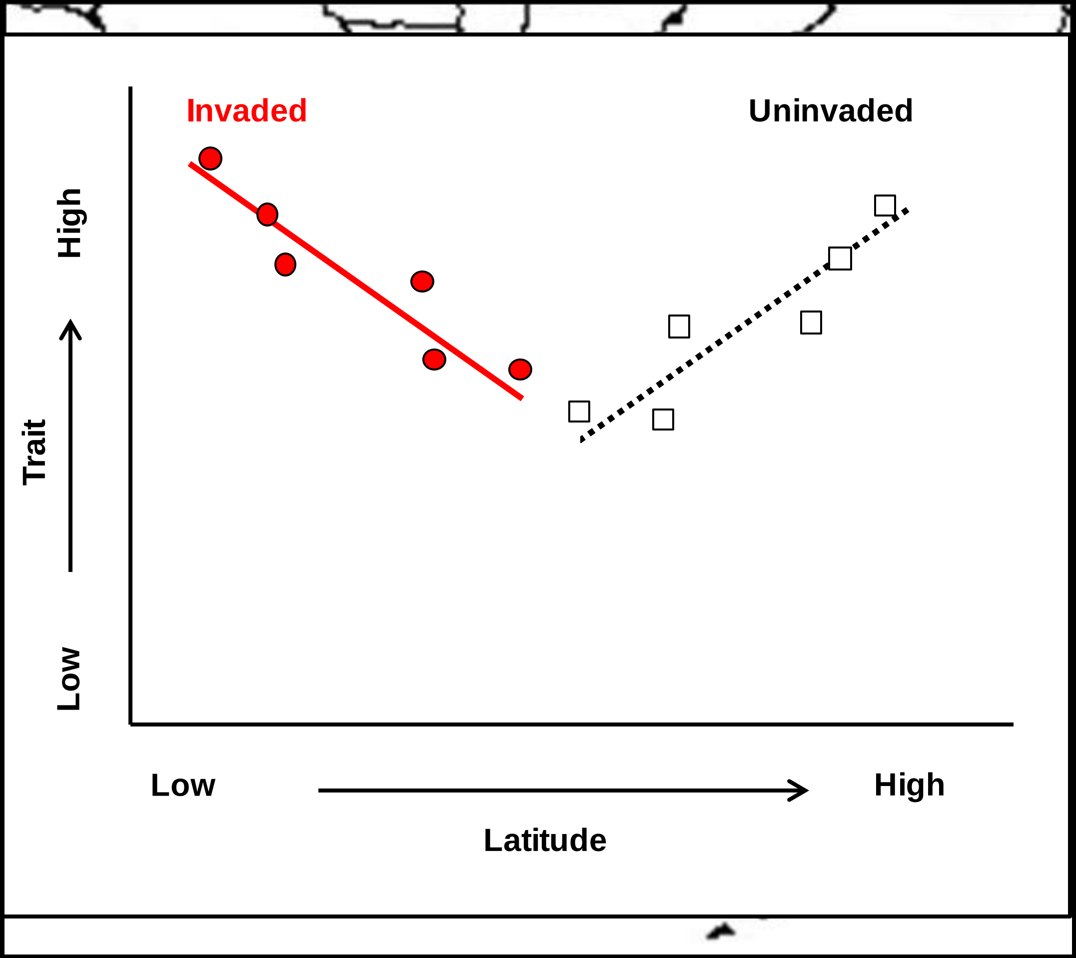


Do fire ants alter preexisting spatial patterns in fence lizard traits?

Problem:
- No time machine

Solution
- Sample farther north

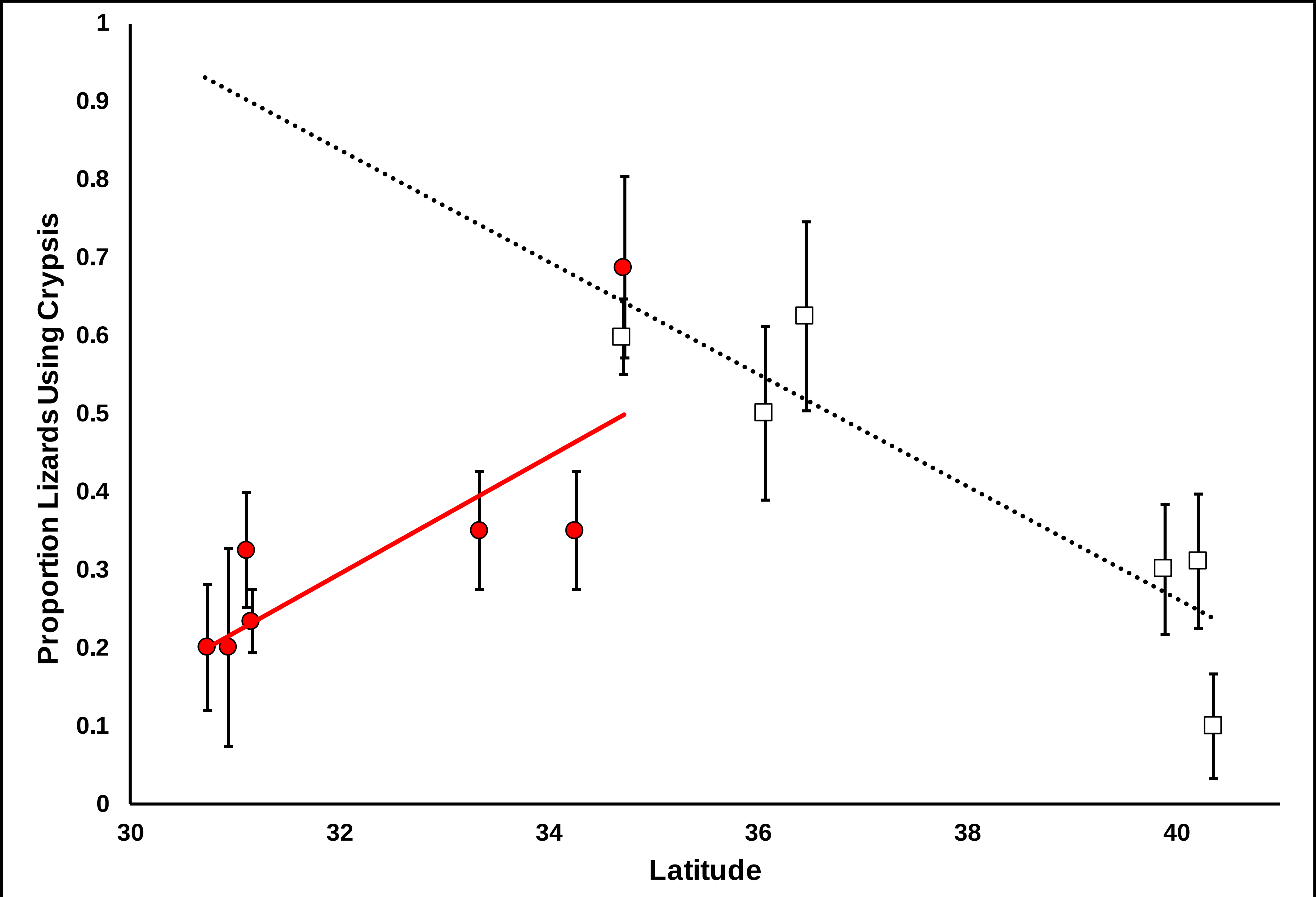
Measure
- Behavior
- Stress Responsiveness
- Hind Limb Length



Anti-Fire Ant Behavior

- Lizards' reactions to attacking fire ants

Behavioral Gradient is Reversed

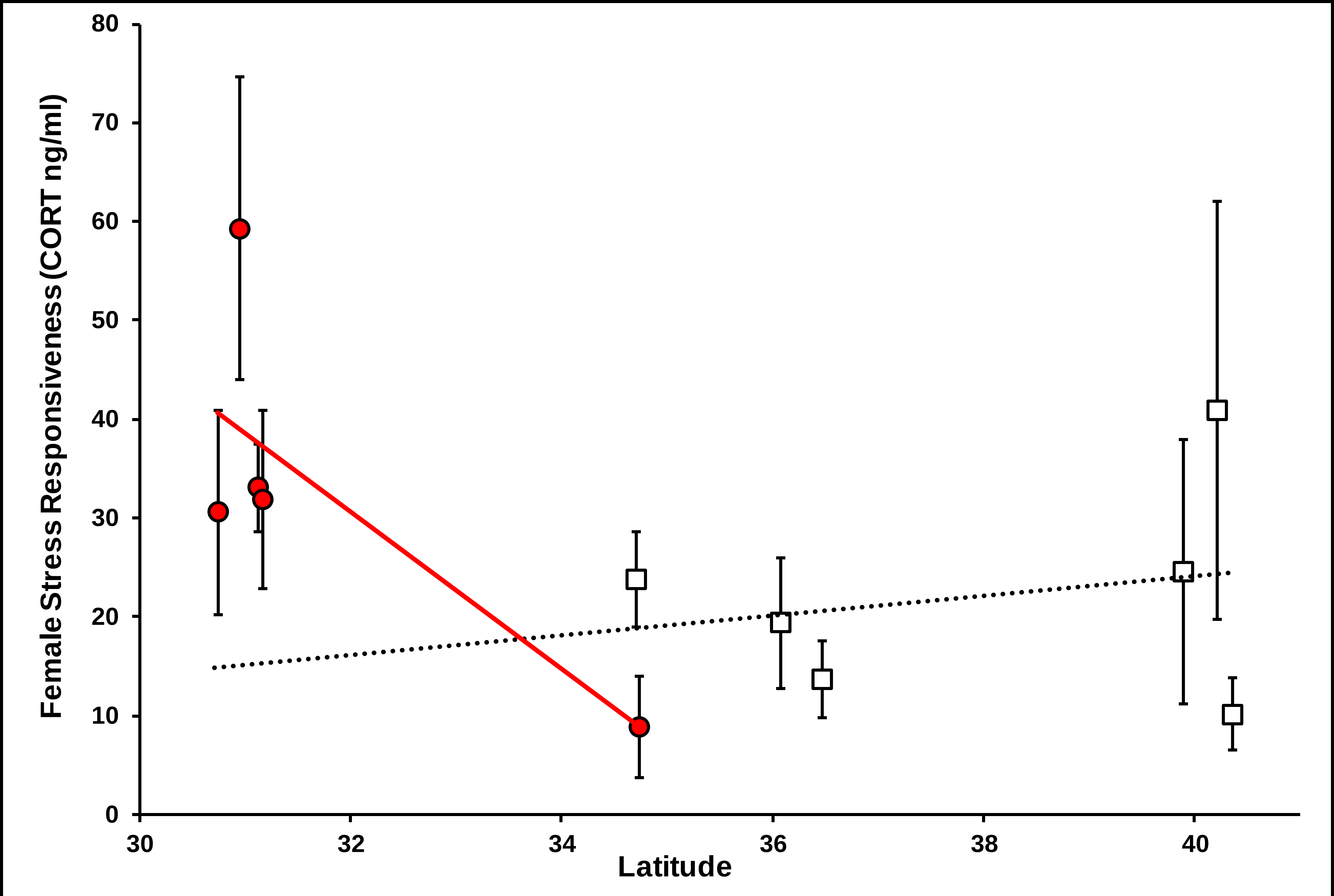


Difference in Slopes; t=5.824, p<0.001

Stress Responsiveness

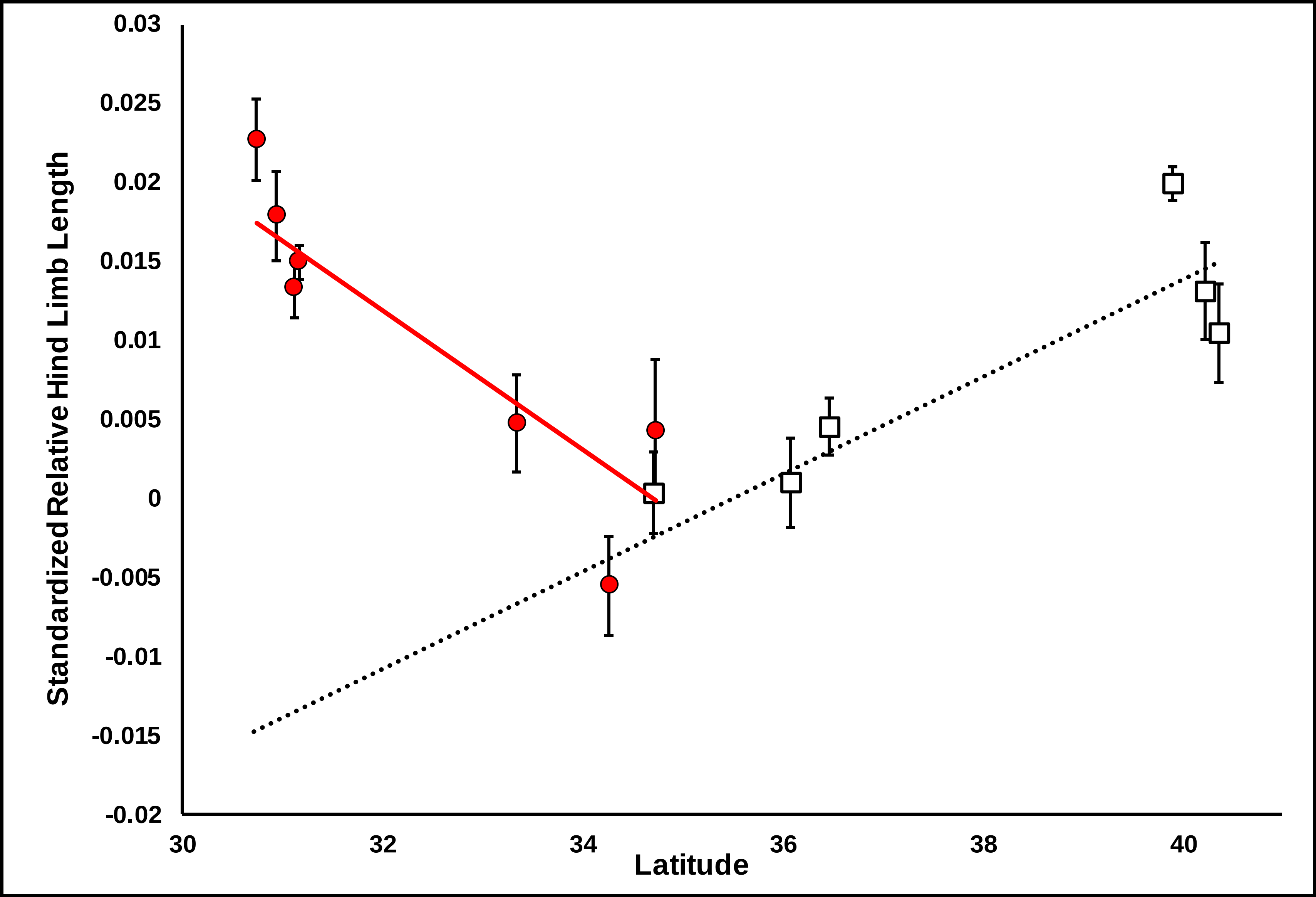
- Corticosterone (CORT)
- Difference between pre- and post-stressor levels

Stress Responsiveness Gradient is Altered



Difference in Slopes; t=-2.423, p=0.017

Morphology Gradient is Reversed

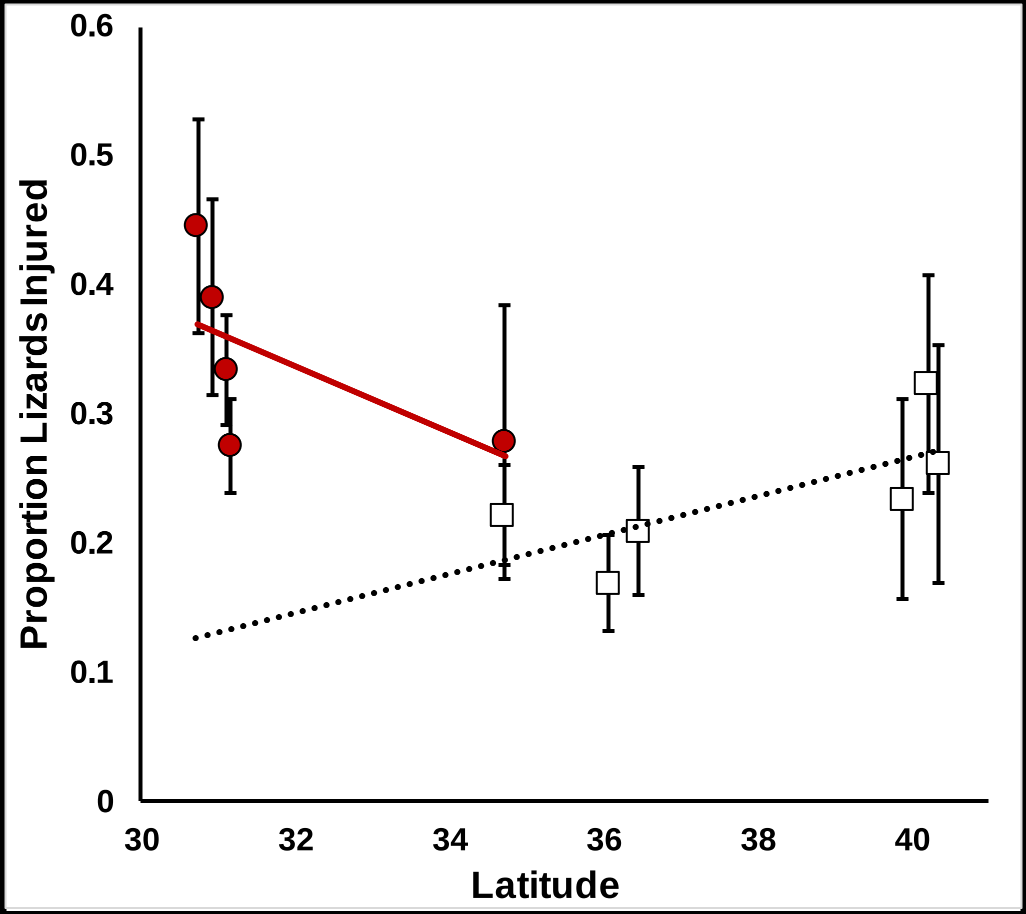


Difference in Slopes; t=-4.444, p<0.001

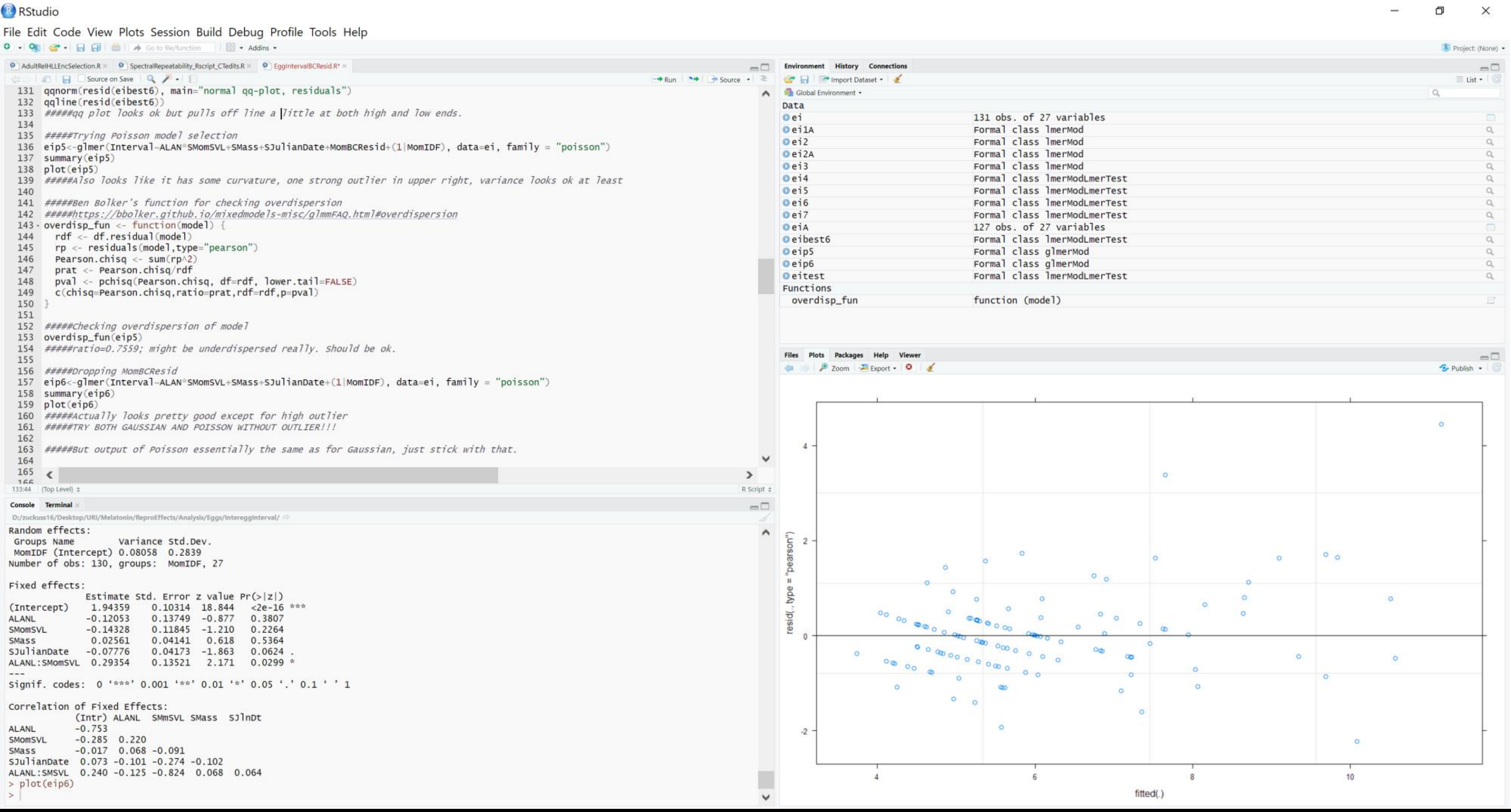
Summary

Invasive fire ants reverse existing gradients in all traits

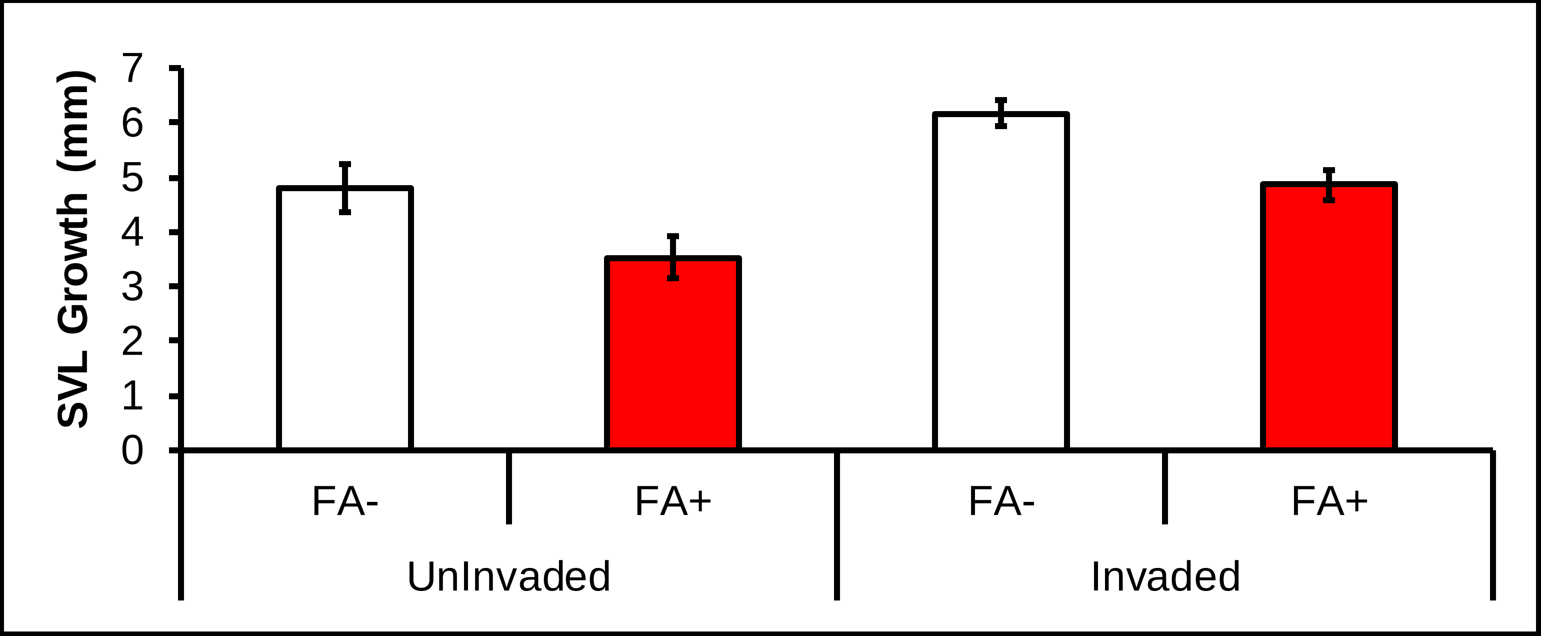
- Large differences between expected and actual values of traits
- Costs?



Data and Analysis



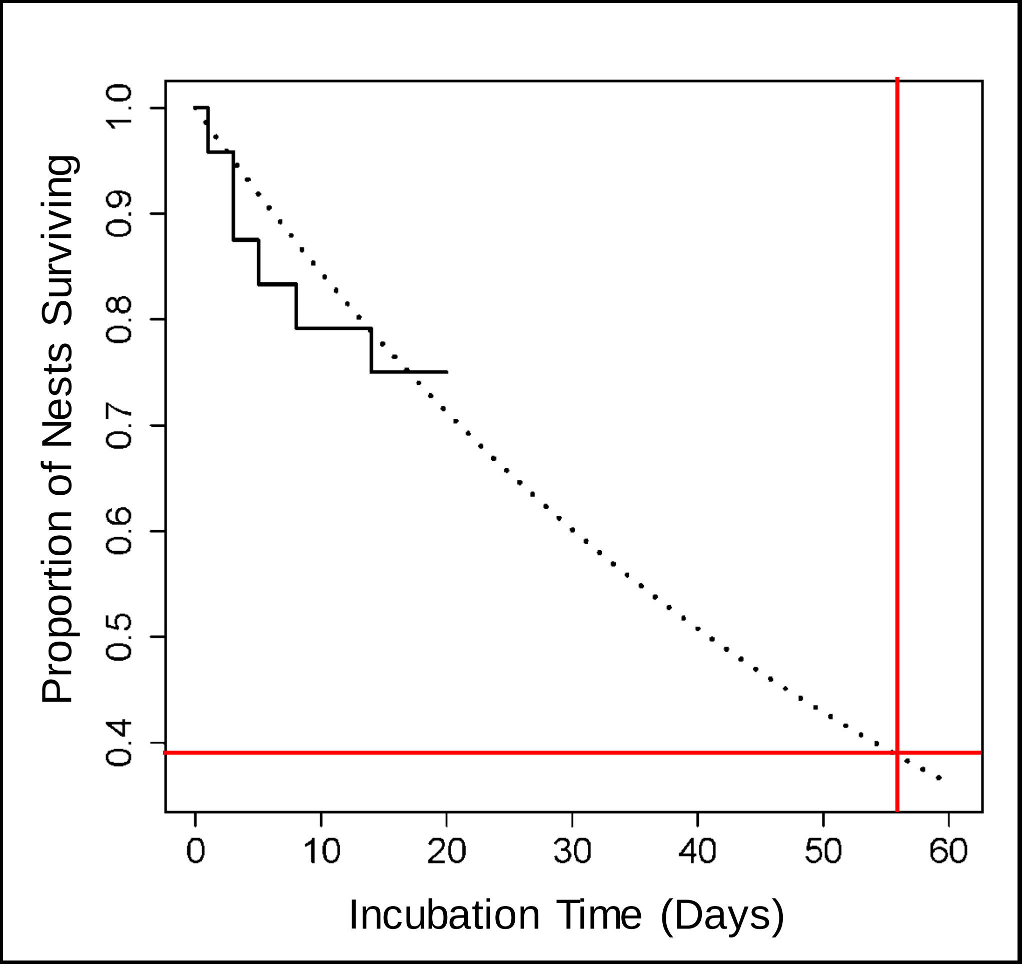
Statistics Minor


SVL Growth (mm)
7
6
5
4
3
2
1
0
FA-
FA+
FA-
FA+
UnInvaded
Invaded

Data and Analysis

- Continuous Data

- Linear mixed models



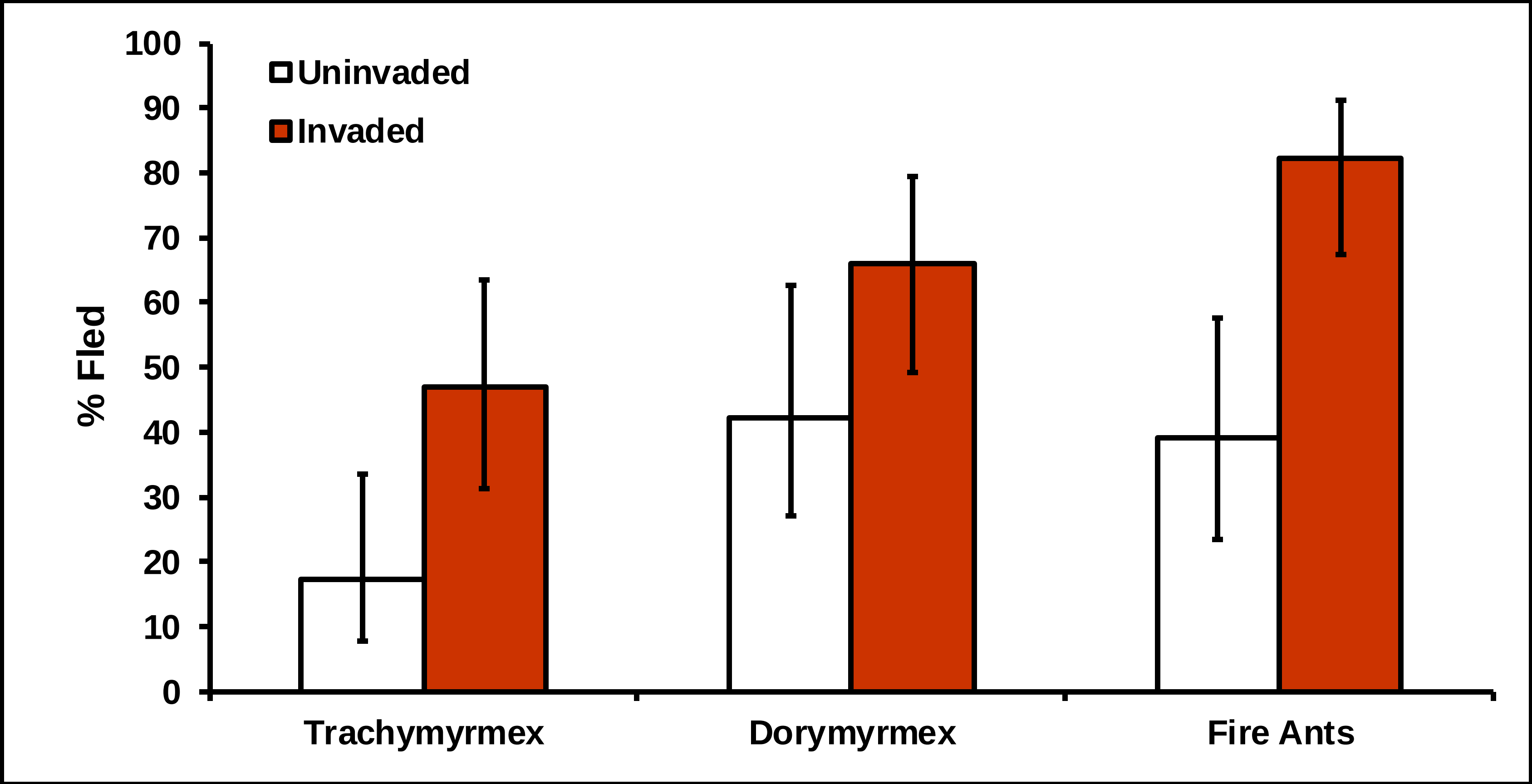
Proportion of Nests Surviving
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0
10
20
30
40
50
60
Incubation Time (Days)

Data and Analysis

- Continuous Data
- Survival Data

- Linear mixed models
- Survival Analysis

Invaded Lizards Flee More From All Ants

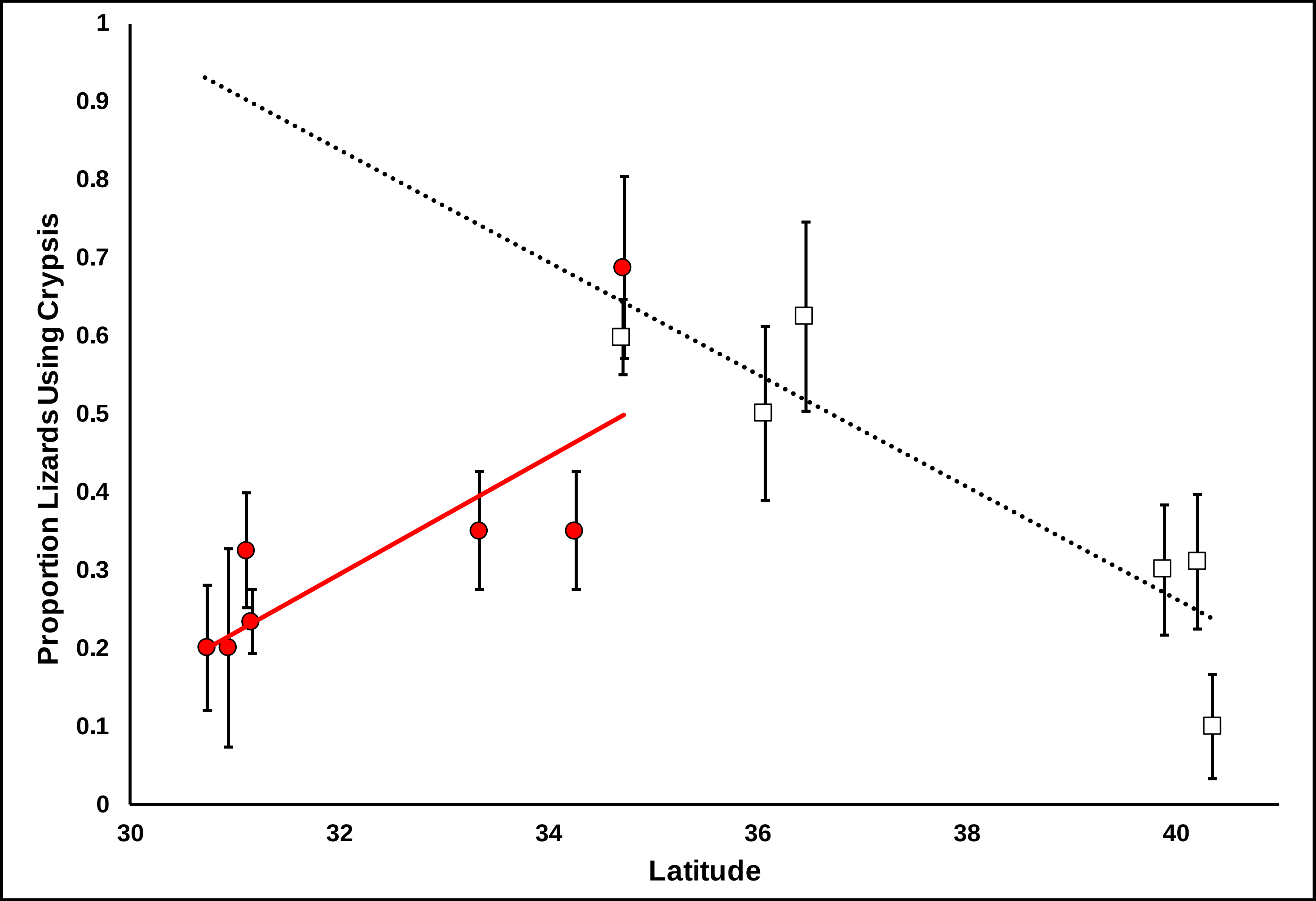


Data and Analysis

- Continuous Data
- Survival Data
- Binomial Data

- Linear mixed models
- Survival Analysis
- Generalized linear mixed models

Behavioral Gradient is Reversed



Data and Analysis

- Continuous Data
- Survival Data
- Binomial Data
- Spatial data

- Linear mixed models
- Survival Analysis
- Generalized linear mixed models
- More and more complex models…

The Future of Ecology

- Is increasingly quantitative
- Ecology requires new skillsets:
  - Computational
  - Programming
  - Mathematics
- Predictions
- Transparency
- Data analyst
  - >$100,000/year

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